NASA SP-7037 (290)
April 1993

AERONAUTICAL ENGINEERING

A CONTINUING BIBLIOGRAPHY WITH INDEXES

NASA STI PROGRAM
SCIENTIFIC & TECHNICAL INFORMATION

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NASA
National Aeronautics and Space Administration
Scientific and Technical Information Program
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INTRODUCTION

This issue of *Aeronautical Engineering—A Continuing Bibliography* (NASA SP-7037) lists 1396 reports, journal articles, and other documents recently announced in the NASA STI Database.

Accession numbers cited in this issue include:

Scientific and Technical Aerospace Reports (STAR) (N-10000 Series)	N93-15659 — N93-19412
International Aerospace Abstracts (IAA) (A-10000 Series)	A93-17521 — A93-23760

The coverage includes documents on the engineering and theoretical aspects of design, construction, evaluation, testing, operation, and performance of aircraft (including aircraft engines) and associated components, equipment, and systems. It also includes research and development in aerodynamics, aeronautics, and ground support equipment for aeronautical vehicles.

Each entry in the publication consists of a standard bibliographic citation accompanied in most cases by an abstract. The listing of the entries is arranged by the first nine *STAR* specific categories and the remaining *STAR* major categories. This arrangement offers the user the most advantageous breakdown for individual objectives. The citations include the original accession numbers from the respective announcement journals.

Seven indexes—subject, personal author, corporate source, foreign technology, contract number, report number, and accession number—are included.

A cumulative index for 1993 will be published in early 1994.

Information on availability of documents listed, addresses of organizations, and CASI price schedules are located at the back of this issue.

CONTENTS

TYPICAL REPORT CITATION AND ABSTRACT

NASA SPONSORED

ON MICROFICHE

ACCESSION NUMBER → **N93-10098*#** Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics. ← CORPORATE SOURCE

TITLE → **NAVIER-STOKES DYNAMICS AND AEROELASTIC COMPUTATIONS FOR VORTICAL FLOWS, BUFFET AND AEROELASTIC APPLICATIONS Progress Report, 1 Oct. 1991 - 30 Sep. 1992**

AUTHOR → OSAMA A. KANDIL Sep. 1992 38 p ← PUBLICATION DATE

CONTRACT NUMBER → (Contract NAG1-648)

REPORT NUMBERS → (NASA-CR-190692; NAS 1.26:190692) Avail: CASI HC A03/MF A01 ← PRICE CODE ← AVAILABILITY SOURCE

The accomplishments achieved during the period include conference and proceedings publications, journal papers, and abstracts which are either published, accepted for publication or under review. Conference presentations and NASA highlight publications are also included. Two of the conference proceedings publications are attached along with a Ph.D. dissertation abstract and table of contents. In the first publication, computational simulation of three-dimensional flows around a delta wing undergoing rock and roll-divergence motions is presented. In the second publication, the unsteady Euler equations and the Euler equations of rigid body motion, both written in the moving frame of reference, are sequetially solved to simulate the limit-cycle rock motion of slender delta wings. In the dissertation abstract, unsteady flows around rigid or flexible delta wings with and without oscillating leading-edge flaps are considered. L.R.R.

TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT

NASA SPONSORED

ACCESSION NUMBER → **A93-12007*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. ← CORPORATE SOURCE

TITLE → **NUMERICAL SIMULATIONS OF HIGH-SPEED FLOWS ABOUT WAVERIDERS WITH SHARP LEADING EDGES**

AUTHORS → KEVIN D. JONES and F. C. DOUGHERTY (Colorado Univ., Boulder) ← AUTHORS' AFFILIATION

JOURNAL TITLE → Journal of Spacecraft and Rockets (ISSN 0022-4650) vol. 29, no. 5 Sept.-Oct. 1992 p. 661-667. Research supported by Univ. of Colorado and DLR refs

CONTRACT NUMBER → (Contract NAG1-880)

Copyright

A procedure is developed for the numerical simulation of stagnation-free inviscid supersonic and hypersonic flows about waveriders with sharp leading edges. The numerical approach involves the development of a specialized grid generator (named HYGRID), an algebraic solution-adaptive grid scheme, and a modified flow solving method. A comparison of the results obtained for several waverider geometries with exact solutions, other numerical solutions, and experimental results demonstrated the ability of the new procedure to produce stagnation-free Euler solutions about sharp-edged configurations and to describe the physics of the flow in these regions. I.S.

AERONAUTICAL ENGINEERING

A Continuing Bibliography (Suppl. 290)

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01

AERONAUTICS (GENERAL)

A93-18327
A MODEL OF THE MAINTENANCE OF A FLEET OF TU-204 AIRCRAFT AT A MAINTENANCE AND REPAIR CENTER [MODEL' PROTSESSA TEKHNICHESKOI EKSPLUATATSII SAMOLETNOGO PARKA TU-204 V USLOVIIAKH FUNKTSIONIROVANIIA TSENTRA TEKHNICHESKOGO OBSLUZHIVANIIA I REMONTA]
A. M. ANDRONOV, M. K. BOGOMOLOV, and V. V. SMELOV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 3-6. In Russian.
Copyright

A simulation model has been developed for the maintenance of a fleet of TU-204 aircraft at a central maintenance and repair facility. The model provides a way to evaluate the efficiency of various maintenance solutions and to analyze the effect of various factors on the maintenance work. The principal features of the model, which has been implemented in computer software, are briefly discussed. V.L.

A93-18352
IMPROVEMENT OF AIRCRAFT MAINTENANCE METHODS [SOVERSHENSTVOVANIE METODOV EKSPLUATATSII LETATEL'NYKH APPARATOV]
N. I. VLADIMIROV, ED. Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 123 p. In Russian.
Copyright

The papers contained in this volume provide an overview of theoretical and experimental research aimed at improving the operation and maintenance of aircraft, developing advanced methods of engine diagnostics, and increasing the efficiency of aircraft utilization and flight safety. Topics discussed include methods of controlling the gas content of hydraulic system fluids, a multiple approach to hydraulic pump diagnostics, and characteristics of the diagnostics of booster system components. Papers are also presented on the assessment of flight data in real time, effect of temperature conditions on the life of hydraulic system bearings, and selection of the time scale for prophylactic measures under service conditions. (For individual items see A93-18353 to A93-18375) V.L.

A93-18375
SELECTION OF THE TIME SCALE FOR PREVENTIVE MEASURES UNDER SERVICE CONDITIONS [VYBOR VREMENNOI SHKALY DLIA PROVEDENIIA PROFILAKTICHESKIKH MEROPRIIATII V USLOVIIAKH EKSPLUATATSII]
S. V. SHUL'ZHIK *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 115-120. In Russian. refs
Copyright

Several different time scales and their linear combination are considered for use as the basis for the preventive maintenance of aircraft systems. Based on results of fatigue testing, it is demonstrated that a linear combination of different time scales can be selected that would provide the most accurate estimates of reliability indices, thus minimizing economic losses due to the exhaustion of the assigned service life. V.L.

A93-18376
PROBLEMS IN THE AERODYNAMICS AND DYNAMICS OF FLIGHT VEHICLES IN THE LIGHT OF K.E. TSIOLKOVSKY'S IDEAS; LECTURES DEVOTED TO K.E. TSIOLKOVSKY'S IDEAS, 25TH, KALUGA, RUSSIA, SEPT. 11-14, 1990, TRANSACTIONS [VOPROSY AERODINAMIKI I DINAMIKI LETATEL'NYKH APPARATOV V SVETE IDEI K.E. TSIOLKOVSKOGO; CHTENIIA, POSVIASHCHENNYE IDEIAM K.E. TSIOLKOVSKOGO, 25TH, KALUGA, RUSSIA, SEPT. 11-14, 1990, TRUDY]
S. A. POPYTALOV, ED., V. I. MAVRITSKII, ED., R. V. PIATYSHEV, ED., A. M. TARASENKOV, ED. et al. Moscow AN SSSR, Institut Istorii Estestvoznaniia i Tekhniki 1991 89 p. In Russian.
Copyright

The papers presented in this volume focus on current theoretical and experimental research in the field of flight vehicle dynamics and aerodynamics, emphasizing the relation between this research and Tsiolkovsky's ideas. Topics discussed include the method and results of studies of flow past supersonic flight vehicles at moderate and large angles of attack, solution of trajectory optimization problems in flight dynamics using the Pontriagin maximum principle, and a method of turbulent atmosphere modeling. Papers are also presented on the evaluation of the external loading of airships in flight, small-volume tethered aerostat systems, and selection of the area of the tail surfaces of airships on the basis of a statistical analysis. (For individual items see A93-18377 to A93-18389) V.L.

A93-18754
KEY TRENDS IN HUMAN FACTORS OF AIRCRAFT MAINTENANCE; PROCEEDINGS OF THE CONFERENCE, LONDON, UNITED KINGDOM, OCT. 31, 1991
London Royal Aeronautical Society 1991 109 p.
(ISBN 1-85768-0057) Copyright

The present conference discusses the European viewpoint in aircraft maintenance developments, design-for-safety criteria and practices, the role of human factors considerations in aircraft maintenance and ground handling, the changing demands of technical training for aircraft maintenance personnel, and the benefits of ground maintenance simulators. Also treated are the aircraft maintenance effects of built-in test equipment relative to the exercise of human judgment, the effect of aircraft maintenance on human factors, the use of information systems in association with new aircraft maintenance technologies, and the integration of requirements for ground-based maintenance data systems. (For individual items see A93-18755 to A93-18760) O.C.

A93-18756
THE HUMAN FACTORS ASPECTS OF AIRCRAFT GROUND HANDLING
PETER PUTNAM (British Aerospace /Commercial Aircraft/, Ltd., Bristol, United Kingdom) *In* Key trends in human factors of

ABSTRACTS

aircraft maintenance; Proceedings of the Conference, London, United Kingdom, Oct. 31, 1991 London Royal Aeronautical Society 1991 p. 4.1-4.15.
Copyright

An exploration is conducted of the human factors considerations proper to aspects of aircraft ground-handling; these aspects encompass servicing, 'apron' equipment, turnaround times, accessibility and simplicity of equipment, maintenance tasks, equipment commonality, and health and safety considerations. Attention is given to the direct and indirect operating cost effects of each of these factors, as well as to the introduction and evaluation of novel equipment and the servicing/loading ground configurations associated with Airbus airliners. O.C.

A93-18757
THE BENEFITS OF GROUND MAINTENANCE SIMULATORS
JOHN CARLTON and ALISTAIR POWELL (Rediffusion Simulation, Ltd., Crawley, United Kingdom) *In* Key trends in human factors of aircraft maintenance; Proceedings of the Conference, London, United Kingdom, Oct. 31, 1991 London Royal Aeronautical Society 1991 p. 6.1-6.5.
Copyright

An account is given of the types of maintenance-training devices, such as simulators, that are currently being used around the world, as well as an evaluation of their benefits and operational modes. Within a simulator, a ground crew is better able to understand systems and to trace apparent faults, as well as to indicate the actions needed to rectify such situations. Choice of the appropriate syllabus leads to the establishment of the requisite ground-crew expertise without diverting revenue-earning aircraft for training purposes. O.C.

A93-18758
LOOKING AND SEEING - A PRACTICAL PROBLEM
DAVE LEWENDON (British Airways Engineering, Hounslow, United Kingdom) *In* Key trends in human factors of aircraft maintenance; Proceedings of the Conference, London, United Kingdom, Oct. 31, 1991 London Royal Aeronautical Society 1991 p. 7.1-7.9.
Copyright

An account is given of the knowledge and skills required for sound judgment and reasonable assessment during routine maintenance schedule inspection. The detection and judgment skills of a certifying engineer are essential in maintaining the airworthiness of an aircraft. Attention is given to inspection criteria for structural damage, mechanical systems, and avionics; a training course is formulated. O.C.

A93-18759
BITE VS HUMAN JUDGEMENT - THE AIRCRAFT SIDE
GAUTHAM RAMOHALLI (Honeywell, Inc., Air Transport Systems Div., Phoenix, AZ) *In* Key trends in human factors of aircraft maintenance; Proceedings of the Conference, London, United Kingdom, Oct. 31, 1991 London Royal Aeronautical Society 1991 p. 9.1-9.7. refs
Copyright

The capabilities of powerful microprocessors are being exploited for both the enhancement of avionics and the mastery of their maintenance requirements by more highly automated means. An onboard maintenance system (OMS) processes raw symptoms from built-in test equipment (BITE) to present a problem's consolidated higher-level diagnosis. The judgments formed by a perspicacious and experienced maintenance crew remains necessary for the making of final decisions under stringent time pressures. The benefits which such a maintenance crew will derive from an OMS's reading of BITE are presently evaluated. O.C.

A93-18760
INTEGRATING THE MAINTENANCE REQUIREMENT MAINTENANCE GROUND BASED DATA SYSTEMS - THE MISSING LINK?
A. J. GOODY (RAF, London, United Kingdom) *In* Key trends in human factors of aircraft maintenance; Proceedings of the Conference, London, United Kingdom, Oct. 31, 1991 London Royal Aeronautical Society 1991 p. 12.1-12.7. refs
Copyright

An account is given of the requirements for the design and implementation of an integrated maintenance-information 'ground-based data system' (GBDS) that can reduce technical and logistic-support manning to more economical levels, and even diminish personnel-training requirements. The GBDS must, however, be suitably integrated into both the aircraft and the existing logistics support system structure. O.C.

A93-18761
ARTIFICIAL INTELLIGENCE TECHNIQUES FOR IMPROVING AIRCRAFT MAINTENANCE EFFICIENCY; PROCEEDINGS OF THE CONFERENCE, LONDON, UNITED KINGDOM, FEB. 21, 1991
London Royal Aeronautical Society 1991 67 p.
(ISBN 0-903409-84-4) Copyright

The present conference discusses expert systems for maintenance engineering, AI as a basis for accuracy and efficiency improvement in aircraft maintenance, RAF experience in aircraft-maintenance AI, and knowledge-based systems and avionics failure diagnosis. Also discussed are expert systems for powerplant fault diagnosis and advanced expert systems for the improvement of aircraft-maintenance efficiency. Attention is given to the ability of AI to readjust check plans in response to emerging disruptions, thereby minimizing the disruptions' effect. (For individual items see A93-18762 to A93-18767) O.C.

A93-18763
CALLING THE RIGHT SHOTS IN AIRCRAFT MAINTENANCE WITH ARTIFICIAL INTELLIGENCE
B. YANSOUNI (Air Canada, Montreal, Canada) *In* Artificial intelligence techniques for improving aircraft maintenance efficiency; Proceedings of the Conference, London, United Kingdom, Feb. 21, 1991 London Royal Aeronautical Society 1991 p. 2.1-2.12.
Copyright

A commercial aircraft operator's experience to date with the use of AI techniques in aircraft 'C-check' overhauls, which occur prior to a given aircraft's reaching of a predetermined number of flying hours and landings, is presented and evaluated. C-checks are often delayed due to disruptions of the overhaul plan; attention is presently given to the ability of AI to readjust check plans, thereby minimizing their disruptive effects. O.C.

A93-18765
KNOWLEDGE BASED SYSTEMS AND AVIONIC EQUIPMENT FAILURE DIAGNOSIS
RICK MAGALDI (British Airways, PLC, Hounslow, United Kingdom) *In* Artificial intelligence techniques for improving aircraft maintenance efficiency; Proceedings of the Conference, London, United Kingdom, Feb. 21, 1991 London Royal Aeronautical Society 1991 p. 4.1-4.5. refs
Copyright

The application of knowledge-based systems (KBSs) technology to aircraft equipment failure diagnostics has been found to yield significant improvements in maintenance efficiency and quality in virtue of their refined problem-solving logic. Attention is presently given to a commercial operator's experience with KBS-equipped automates test equipment and built-in error testing systems, in the course of implementing a Computer-Aided Decision and Diagnostics Information System program. O.C.

A93-18767
ADVANCED EXPERT SYSTEMS INCREASE AIRCRAFT MAINTENANCE EFFICIENCY - AN OVERVIEW
STEVE DOCKER (Advanced Expert Systems, Ltd., Derby, United Kingdom) *In* Artificial intelligence techniques for improving aircraft maintenance efficiency; Proceedings of the Conference, London, United Kingdom, Feb. 21, 1991 London Royal Aeronautical Society 1991 p. 7.1-7.7.
Copyright

systems are presently noted to be able to accelerate a... ,aintenance-related problem-solving processes, while achiev.. g a high consistency in decisionmaking and maximizing the distribution of organizational expertise. It is also possible to integrate advanced expert systems with conventional applications programs to furnish powerful aircraft maintenance software tools. O.C.

A93-18779
SAFETY THROUGH INTEGRITY AND RELIABILITY
P. C. RUFFLES (Rolls-Royce, PLC, Derby, United Kingdom) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 1.1-1.5.
Copyright

The achievement of integrity and reliability in aircraft gas turbines, such as those presently considered for reliability-critical twin-engined trans-Atlantic airliners and advanced STOVL aircraft, is rooted in design, manufacturing, development and operation procedures. Computer-based modelling systems, in conjunction with advanced testing facilities, have facilitated the creation of lightweight engines with full integrity over minimum development times. O.C.

A93-18788
ENGINE RELIABILITY FROM AN INDEPENDENT OVERHAUL SHOPS PERSPECTIVE
A. L. RUSSELL (H+S Aviation, Ltd., Bristol, United Kingdom) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 10.1-10.9.
Copyright

Independent overhaul establishments for aircraft engines, in contrast with those operated by engine manufacturers and commercial aircraft operators, must maximize profit in the absence of any alternative source of revenue. They can in general only maximize the level of reliability inherent in the given engine's design concept. An effort is made to detail the ways in which the role of the independent overhauler is to keep reliability affordable; this has prompted continuous investigation of parts-repairability possibilities, alerting manufacturers to emerging prospects for incorporation into future hardware designs. O.C.

A93-19461
OVERVIEW OF THE JAPANESE NATIONAL PROJECT FOR SUPER/HYPER-SONIC TRANSPORT PROPULSION SYSTEM
OSAMU ICHIMARU (Agency of Industrial Science and Technology, Tokyo, Japan), MAKOTO ISHIZUKA (New Energy and Industrial Technology Development Organization, Tokyo, Japan), and KANJI MURASHIMA (Engineering Research Association for Super/Hypersonic Transport Propulsion Systems, Japan) Jun. 1992 5 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992
(ASME PAPER 92-GT-252)

An account is presented of the program-organization structure of Japan's effort to produce a powerplant capable of sustaining the cruise of an SST/HST commercial transport at up to Mach 5. Primary responsibility for program management lies with the Agency of Industrial Science and Technology. The R&D elements of the program are fourfold: (1) definition of ramjet component design; (2) definition of high performance turbojet design; (3) design of a FADEC with electrooptic sensors; and (4) integration of all components of the propulsion system. O.C.

A93-21850
WATER INSTEAD OF CHEMICAL CORROSIVES AGAINST AIRCRAFT PAINT - ENVIRONMENT-FRIENDLY PAINT-STRIPPING METHODS COULD MEAN DRASTIC COST REDUCTIONS FOR THE AIRCRAFT INDUSTRY
New-Tech News (ISSN 0935-2694) vol. 3 1992 p. 21-23.
Copyright

This paper describes an environmentally friendly alternative for removing aircraft paint. The technique utilizes a thin stream of water to strip paint off surfaces. Rotating nozzles fan out the stream so that the aircraft surface remains undamaged despite enormous water pressure. R.E.P.

A93-22307#
GERMAN UNIVERSITY RESEARCH IN HYPERSONICS
E. KRAUSE (Aachen, Rheinisch-Westfaelische Technische Hochschule, Germany) Dec. 1992 10 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5033) Copyright

A review is presented of three research programs initiated by the German Research Association in 1989 and 1990 on hypersonic research. To provide some insight into the work in progress since initiation of the programs, results selected from aerothermodynamic research are discussed. In aerothermodynamics, research is aimed at determining aerodynamic forces and moments, analyzing propulsion systems, and reentry problems. R.E.P.

A93-22698
BATTLE DAMAGE REPAIRS
GEOFFREY COOPER Aerospace (UK) (ISSN 0305-0831) vol. 19, no. 12 Dec. 1992 p. 12-14.
Copyright

An overview is presented of the background and growth in aircraft battle damage repair methods including recent related details from the Gulf War. As air forces are no longer able to afford reserves to replace aircraft lost in action the importance of rapid battle damage repairs in the field increases. Battleworthiness is becoming an important aspect of new aircraft design and battle damage repair manuals have to be issued by the manufacturer when a new aircraft enters service. R.E.P.

N93-15946# National Aerospace Lab., Tokyo (Japan).
SPECIAL PUBLICATION OF NATIONAL AEROSPACE LABORATORY
Sep. 1991 97 p
(DE93-716176; SP-15) Avail: CASI HC A05/MF A02

The lectures are classified by theme into the following: receptivity and instability; three-dimensional boundary-layer transition; development of vortexes and turbulence structure; transition and control of turbulence; etc. In the study on receptivity and instability, analyses using nonlinear amplitude equations are made on receptivity of boundary layers, especially numerical simulations of conditions under which disturbances excite T-S waves and interference of N-number unstable modes. In the study of transition of three dimensional boundary layers, the experiment was conducted to elucidate the turbulence transition process of a swept wing and a swept cylinder. In the study on the development of vortexes and turbulence structure, reported is the experiment on response to the sound of the high shear layer which is formed by exciting longitudinal vortex pair using blowout from the wall slit. In the study on transition and control of turbulence, made are investigations on the effect of triangle riblets on turbulent flow transition of boundary layers and the numerical simulation by the spectral method on convective secondary flows generated in the flow in the rectangular duct of which the bottom and the side walls are heated. DOE

N93-15949# National Aerospace Lab., Tokyo (Japan).
SPECIAL PUBLICATION OF NATIONAL AEROSPACE LABORATORY
Dec. 1991 354 p
(DE93-716195; SP-16) Avail: CASI HC A16/MF A03

This is the proceedings of the 9th symposium on aircraft computational aerodynamics held during 12-14 June 1991 at National Aerospace Laboratory. At the symposium, 53 studies were reported, and a number of advanced computational methods to challenge the most up-to-date problems in fluid dynamics were developed. The following technologies were discussed: modeling of complicated flows in the contest of space engineering; high-speed computation technology, mainly the development of

simulation methods; technology supporting wind tunnel tests; and developments in making image processing technology applicable.
DOE

N93-16465# Manchester Univ. (England). Aeronautical Engineering Group.
THE GOLDSTEIN AERONAUTICAL ENGINEERING RESEARCH LABORATORY
1991 59 p
(AERO-REPT-9109; ETN-92-92777) Avail: CASI HC A04/MF A01
The Goldstein Laboratory (England) houses one of the largest university based aerodynamic facilities in Europe. It is also the operational headquarters of a company conducting research and testing in all areas of fluid mechanics and aerodynamics. The following are addressed: the director and former directors of the laboratory; laboratory and computer resources; location of the Goldstein Laboratory; history of the laboratory and the school of aeronautical engineering; laboratory layout; experimental facilities.
ESA

N93-17666# Naval Postgraduate School, Monterey, CA.
A DATABASE APPROACH TO AIRCRAFT CARRIER AIRPLAN PRODUCTION M.S. Thesis
ROBERT M. STAMMER Sep. 1992 76 p
(AD-A257737) Avail: CASI HC A05/MF A01
This thesis addresses a known problem in carrier aviation: the constant duplication of effort in writing the carrier airplan. This problem is common to all airwings and results in late airplan publish times which reduce the combat effectiveness of the battlegroup. The analysis of the airplan is accomplished through the establishment of a database of carrier airplans. The database interacts with a spreadsheet designed to help strike operations aboard the carrier streamline the process of writing the airplan. The prototype model developed accepts inputs from the Assistant Strike Operations Officer. The model searches the database for airplans that conform to his inputs and provides candidate airplans for review. Once an airplan is selected, an airplan template, in spreadsheet format, can be altered to meet any required changes. Once changed to meet specific tasking the final product can be saved. After a period of operations, the database search file can be updated to mold the database to a specific ship and airwing's standard operating routine.
GRA

N93-17732# Federal Aviation Administration, Atlantic City, NJ.
PROCEEDINGS OF THE AIAA/FAA JOINT SYMPOSIUM ON GENERAL AVIATION SYSTEMS
GUS FERRARA and KAREN MASON Jun. 1992 516 p
Proceedings held in Wichita, KS, 16-17 Mar. 1992
(AD-A257780; DOT/FAA/CT-92/17) Avail: CASI HC A22/MF A04
The 1992 AIAA/FAA Joint Symposium on General Aviation Systems was the result of the combined efforts of the AIAA General Aviation Systems Technical Committee and the Federal Aviation Administration Technical Center. This symposium offered the opportunity to present and review the current state of the art in research that is being conducted in support of general aviation. All told, the papers presented covered the entire spectrum of research, and the participants had the opportunity to hear presentations on everything from alternate fuels to developments in air traffic control.
GRA

N93-17883*# International Technical Associates, Inc., Drexel Hill, PA.
OPEN AIRSCREW VTOL CONCEPTS
W. Z. STEPNIEWSKI and T. TARCZYNSKI Sep. 1992 226 p
(Contract NAS2-12819)
(NASA-CR-177603; A-93020; NAS 1.26:177603) Avail: CASI HC A11/MF A03
The following concepts, based on using open airscrew(s) for VTOL maneuvers, are re-examined in light of current technology: (1) tip-driven helicopters, (2) compound helicopters; and (3) high-speed VTOL aircraft, represented by tiltrotors, tiltwings, retractoplanes and stoppable rotors. Criteria, permitting one to compare performance of aircraft using diverse lifting and propelling methods are established. Determination of currently possible performance, indication of near-future potentials, and comparison of those items with the baseline levels (as represented by contemporary shaft-driven helicopters, first generation tiltrotors, and commercial turboprop fixed-wind aircraft) constitutes bulk of this report.
Author

N93-18887# Air Force Inst. of Tech., Wright-Patterson AFB, OH.
AN INVESTIGATION OF THE INFLUENCE OF ADVANCED AIRCRAFT DIAGNOSTICS ON THE TECHNOLOGICAL SOPHISTICATION OF MAINTENANCE PERSONNEL M.S. Thesis
CHRIS R. COLLINS and CLETE W. KNAUB Sep. 1992 114 p
(AD-A258988; AFIT/GLM/LSM/92S-9) Avail: CASI HC A06/MF A02
The purpose of this research was to determine what effect automated diagnostic systems will have on the maintenance worker's technological capabilities. Four investigative questions guided the project: (1) what effect has automation of skilled jobs had on workers in the civilian community?; (2) what technological and psychological traits have led to success in past military conflicts?; (3) what types of technological and psychological traits will technicians have who are heavily dependent on diagnostic systems? (for example, to what degree will maintenance technicians be able to improvise when deployed to a combat area?); and (4) what lessons can Air Force maintenance managers learn from the civilian community and past military experience? The study was conducted by performing a literature review of material from both military operational data and civilian data regarding automation and expert systems. Answers to the research questions were inferred from the collective resources studied. The study found that automation has impacted workers' technological capabilities in the past. Additionally, traits of successful technological workers were identified. Guidance helpful to managers and engineers implementing advanced diagnostics is also provided within the research.
GRA

N93-19002# Technische Univ., Delft (Netherlands). Vakgroep Ontwerpen, Vliegmechanica en Ruimtevaart.
PROFESSOR WITTENBERG: HIS SPECIALITY AND VERSATILITY [PROFESSOR WITTENBERG: ZIJN VAKGEBIED EN ZIJN VEELZIJDIGHEID]
1991 89 p In DUTCH Symposium Amicorum held in Delft, Netherlands, 25 Jan. 1991
(ISBN-90-6275-670-0; ETN-92-92169) Copyright Avail: CASI HC A05/MF A01
Lectures concerning aircraft, given on the superannuation of Professor H. Wittenberg, are presented. Problems of propulsion and aerodynamic drag of aircraft are treated. The activities of Fokker in the field of aircraft performance are summarized. The applications of helicopters are outlined. Research activities in the field of propulsion systems for supersonic and hypersonic aircraft are overviewed. The status and prospects of the Dutch aerospace industry are presented.
ESA

02

AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

A93-17526
THE SCIENCE OF FLIGHT - PILOT-ORIENTED AERODYNAMICS

WILBERT N. HUBIN (Kent State Univ., OH) Ames, IA Iowa State University Press 1992 362 p. refs
(ISBN 0-8138-0398-5) Copyright

An overview is presented of the aerodynamics of flight from the design of aircraft concept through the actual flight regimes experienced by the pilot in control of aircraft. Attention is given to force, mass, and moments, subsonic, transonic, and supersonic fluid flow, and airfoil coefficients. Consideration is given to lift, drag, and power for the complete aircraft, aircraft performance, aircraft design considerations, and aerodynamic simulation. R.E.P.

A93-17750* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
A FINITE ELEMENT STUDY OF INCOMPRESSIBLE FLOWS PAST OSCILLATING CYLINDERS AND AEROFOILS
S. MITTAL and T. E. TEZDUYAR (U.S. Army, High-Performance Computing Research Center; Minnesota Univ., Minneapolis) International Journal for Numerical Methods in Fluids (ISSN 0271-2091) vol. 15, no. 9 Nov. 15, 1992 p. 1073-1118. Research sponsored by Alcoa Foundation refs
(Contract NAG9-449; NSF CTS-87-96352; DAAL03-89-C-0038)
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We present our numerical results for certain unsteady flows past oscillating cylinders and aerofoils. The computations are based on the stabilized space-time finite element formulation. The implicit equation systems resulting from the space-time finite element discretizations are solved using iterative solution techniques. One of the problems studied is flow past a cylinder which is forced to oscillate in the horizontal direction. In this case we observe a change from an unsymmetric mode of vortex shedding to a symmetric one. An extensive study was carried out for the case in which a cylinder is mounted on lightly damped springs and allowed to oscillate in the vertical direction. In this case the motion of the cylinder needs to be determined as part of the solution, and under certain conditions this motion changes the vortex-shedding pattern of the flow field significantly. This nonlinear fluid-structure interaction exhibits certain interesting behavior such as 'lock-in' and 'hysteresis', which are in good agreement with the laboratory experiments carried out by other researchers in the past. Preliminary results for flow past a pitching aerofoil are also presented. Author

A93-17799
PERIODIC EULER AND NAVIER-STOKES SOLUTIONS ABOUT OSCILLATING AIRFOILS
J. Y. TREPANIER, H. ZHANG, M. REGGIO, and M. PARASCHIVOIU (Ecole Polytechnique, Montreal, Canada) Canadian Aeronautics and Space Journal (ISSN 0008-2821) vol. 38, no. 2 June 1992 p. 71-75. Previously announced in STAR as N92-24850 Research supported by NSERC refs

A methodology for solving the unsteady Euler and Navier-Stokes equations around oscillating airfoils is presented. The procedure is composed of a moving grid management algorithm and of a Lagrangian-Eulerian flow solver. Triangular elements have been used to achieve flexible grid movement and adaptation. The scheme for moving grids uses a generalized version of the approximate Riemann solver of Roe which satisfies in an intrinsic way the geometric conversion laws and on which a novel manner to add the viscous terms has been implemented. The methodology has been applied to simulate the flow around an oscillating NACA0012 airfoil. The method was shown to be well adapted to these computations, especially in the Euler case where grid adaptation resulted in a better resolution of the moving shock wave. Author

A93-18222
EFFECT OF AIRFOIL POROSITY ON THE SHOCK WAVE POSITION AND INTENSITY AT TRANSONIC VELOCITIES [O VLIIANII PRONITSAEMOSTI PROFILIA NA POLOZHENIE I INTENSIVNOST' SKACHKA UPLOTNENIIA PRI TRANSZVUKOVYKH SKOROSTIAKH]
A. N. BELOGLAZKIN and V. IA. SHKADOV Moskovskii Universitet, Vestnik, Seriia 1 - Matematika, Mekhanika (ISSN 0579-9368) no. 5 Sept.-Oct. 1992 p. 64-69. In Russian. refs
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Transonic flow over a wing profile with a porous surface is investigated numerically using an implicit method based on a solution to an equation for the full potential. It is shown that there exists an optimal position of the porous region on the airfoil surface which corresponds to the greatest reduction in wave drag. V.L.

A93-18230
BREAKDOWN OF STEADY STATE AXISYMMETRIC FLOW IN A SHOCK LAYER FORMED AS A RESULT OF THE IMPINGEMENT OF A SUPERSONIC UNDEREXPANDED JET ON A PERPENDICULAR PLANE OBSTACLE [RAZRUSHENIE STATSIONARNOGO OSESIMMETRICHNOGO TECHENIIA V UDARNOM SLOE, OBRAZUIUSHCHEMSIA PRI NATEKANII SVERKHZVUKOVOI NEDORASSHIRENNOI STRUI NA PERPENDIKULIARNUIU PLOSKUIU PREGRADU]
E. I. SOKOLOV Rossiiskaia Akademiia Nauk, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 4 July-Aug. 1992 p. 36-42. In Russian. refs
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The mechanism of the breakdown of steady state flow of an ideal gas is investigated by analyzing the evolution of small perturbations in the axial region of the shock layer in the wake of a central shock wave formed during the deceleration of a supersonic underexpanded axisymmetric jet at a perpendicular surface. The boundary value problem is formulated using a linear formulation and solved numerically. V.L.

A93-18233
TWO-PHASE INJECTION FROM THE FRONT SURFACE OF A BLUNT BODY IN HYPERSONIC FLOW [DVUKHFAZNYI VDUV S LOBOVOI POVERKHNOSTI ZATUPLENNOGO TELA V GIPERZVUKOVOM POTOKE]
A. N. OSIPTSOV and E. G. SHAPIRO Rossiiskaia Akademiia Nauk, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 4 July-Aug. 1992 p. 60-66. In Russian. refs
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A mathematical model is presented which describes steady state hypersonic flow of a gas past the front surface of an axisymmetric blunt body with two-phase injection from the surface. Flow in the wall region is described using a two-continuum model of a dusty gas. The problem is solved in the boundary layer and thin viscous shock layer approximations. The carrier and disperse phase distributions near the axis of symmetry are determined through numerical calculations. Determinations are also made of self-similarity parameters determining convective heat transfer. V.L.

A93-18238
INFLUENCE OF SECOND-ORDER BOUNDARY LAYER EFFECTS IN HYPERSONIC FLOW PAST BLUNT CONES OF LARGE ASPECT RATIO [O VLIIANII EFFEKTOV VTOROGO PRIBLIZHENIIA TEORII POGRANICHNOGO SLOIA PRI GIPERZVUKOVOM OBTEKANII PRITUPLENNYKH KONUSOV BOL'SHOGO UDLINENIIA]
D. KH. GAN'ZHA, G. A. TIRSKII, S. V. UTIUZHNIKOV, and M. O. FRIDLENDER Rossiiskaia Akademiia Nauk, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 4 July-Aug. 1992 p. 129-134. In Russian. refs
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The objective of the study was to determine the influence of second-order boundary layer effects on axisymmetric flow past blunt cones and also the applicability regions of approximate methods for including the effect of entropy layer absorption in flow calculations. The gasdynamic model used in the present study includes a system of full equations of a viscous boundary layer containing all the terms of gasdynamic Euler equations and all second-order terms of the asymptotic boundary layer theory. The results obtained are compared with calculations based on Navier-Stokes equations. V.L.

A93-18241
EFFECT OF REAL AIR PROPERTIES ON INTEGRAL AERODYNAMIC CHARACTERISTICS [K VOPROSU O VLIIANII REAL'NYKH SVOISTV VOZDUKHA NA INTEGRAL'NYE AERODINAMICHESKIE KHARAKTERISTIKI]
I. V. EGOROV Rossiiskaia Akademiia Nauk, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 4 July-Aug. 1992 p. 156-164. In Russian. refs
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Results of a mathematical modeling of axisymmetric hypersonic flow past an ellipsoid are presented. The computation data are obtained from the numerical solution of complete Navier-Stokes equations using a finite difference method. Calculations are carried out for the case of laminar flow past the windward part of the body. The effect of the aspect ratio of the ellipsoid on the integral heat flow, pressure drag, and viscous resistance is examined. Results are obtained for three different models of the gas (air): ideal, chemically equilibrium, and chemically nonequilibrium. V.L.

A93-18377
METHOD AND RESULTS OF STUDIES OF FLOW PAST SUPERSONIC FLIGHT VEHICLES AT MODERATE AND LARGE ANGLES OF ATTACK [METOD I REZUL'TATY ISSLEDOVANII OBTEKANIIA SVERKHZVUKOVYKH LETATEL'NYKH APPARATOV NA UMERENNYKH I BOL'SHIKH UGLAKH ATAKI]
S. S. GRAS'KIN and S. A. POPYTALOV *In* Problems in the aerodynamics and dynamics of flight vehicles in the light of K.E. Tsiolkovsky's ideas; Lectures Devoted to K.E. Tsiolkovsky's Ideas 25th, Kaluga, Russia, Sept. 11-14, 1990, Transactions Moscow AN SSSR, Institut Istorii Estestvoznaniia i Tekhniki 1991 p. 3-9. In Russian. refs
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The expanding range of the angles of attack and the increasing flight velocities necessitate the development of new approaches to the study of the aerodynamic characteristics of flight vehicles in these regimes. Here, a new unified approach is proposed for developing a simple but efficient method for studying subsonic and supersonic flow past flight vehicles of complex aerodynamic configurations. Details of the approach are discussed, and the method is demonstrated for delta wings of different aspect ratios. V.L.

A93-18379
THE USE OF THE POLHAMUS AND DISCRETE VORTEX METHODS FOR CALCULATING THE NONLINEAR CHARACTERISTICS OF DELTA WINGS AND WINGS WITH A STRAKE [PRIMENENIE METODOV POL'KHAMUSA I DISKRETNYKH VIKHREI DLIA RASCHETA NELINEINYKH KHARAKTERISTIK TREUGOL'NYKH KRYL'EV I KRYL'EV S NAPLYVOM]
V. A. FROLOV *In* Problems in the aerodynamics and dynamics of flight vehicles in the light of K.E. Tsiolkovsky's ideas; Lectures Devoted to K.E. Tsiolkovsky's Ideas 25th, Kaluga, Russia, Sept. 11-14, 1990, Transactions Moscow AN SSSR, Institut Istorii Estestvoznaniia i Tekhniki 1991 p. 14-19. In Russian. refs
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A method for calculating the nonlinear characteristics of wings is developed which combines the Polhamus method with the method of discrete vortices. The accuracy of the approach is enhanced by using an empirical correction factor. The efficiency and accuracy of the approach are supported by results obtained for delta wings and wings with a strake. V.L.

A93-18384
EFFECT OF THE REYNOLDS NUMBER ON THE AERODYNAMIC CHARACTERISTICS OF A BODY OF REVOLUTION OVER A WIDE RANGE OF ANGLES OF ATTACK [VLIIANIE CHISLA REINOL'DSA NA AERODINAMICHESKIE KHARAKTERISTIKI TELA VRASHCHENIIA V SHIROKOM DIAPAZONE IZMENENIIA UGLA ATAKI]
R. A. ZASOLOV *In* Problems in the aerodynamics and dynamics of flight vehicles in the light of K.E. Tsiolkovsky's ideas; Lectures Devoted to K.E. Tsiolkovsky's Ideas, 25th, Kaluga, Russia, Sept. 11-14, 1990, Transactions Moscow AN SSSR, Institut Istorii Estestvoznaniia i Tekhniki 1991 p. 46-53. In Russian. refs
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In order to estimate the effect of the Reynolds number on the aerodynamic characteristics of a body of revolution at different angles of attack, two geometrically similar models were tested in wind tunnels with test section diameters of 2.2 and 7 m. The model lengths were 1.4 and 5.6 m, respectively, with a length/diameter ratio of 7 for both models. In longitudinal flow, the Re number varied from 1.9 x 10 exp 6 to 4.5 x 10 exp 6 for the smaller model and from 7.7 x 10 exp 6 to 3.7 x 10 exp 7 for the larger model; in transverse flow, the corresponding Re ranges were (2.7-6.4) x 10 exp 5 and (1.1-3.2) x 10 exp 6. The angle of attack varied from 0 to -90 deg. The results, presented in graphic form, indicate that the Re number has a noticeable effect on the aerodynamic characteristics of the models at medium and large angles of attack. V.L.

A93-18499
EXPERIMENTAL STUDY ON THE UNSTEADY AERODYNAMIC RESPONSE OF A THREE DIMENSIONAL CASCADE WITH OSCILLATING BLADES
KAZUHIKO TOSHIMITSU, KEIICHI TAKITA, NOBUHIKO YAMASAKI, and MASANOBU NAMBA Kyushu University, Technology Reports (ISSN 0023-2718) vol. 65, no. 5 Oct. 1992 p. 499-506. In Japanese. refs
Three-dimensional effects on unsteady aerodynamic forces of oscillating blades significantly affect the flutter boundary of cascades. An experimental technique for measuring the fluctuant pressures on blade surfaces under spanwisely nonuniform forced vibration has been developed. The measured pressures agree well with the numerical calculations which are based on modified double linearization theory (DLT). As a result, the three-dimensional effects on unsteady pressure distributions predicted by DLT are experimentally verified. Author

A93-18526* National Aeronautics and Space Administration. *Langley Research Center, Hampton, VA.*
LONGITUDINAL VORTEX CONTROL - TECHNIQUES AND APPLICATIONS (THE 32ND LANCHESTER LECTURE)
D. M. BUSHNELL (NASA, Langley Research Center, Hampton, VA) Aeronautical Journal (ISSN 0001-9240) vol. 96, no. 958 Oct. 1992 p. 293-312. refs
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A summary is presented of vortex control applications and current techniques for the control of longitudinal vortices produced by bodies, leading edges, tips and intersections. Vortex control has up till now been performed by many approaches in an empirical fashion, assisted by the essentially inviscid nature of much of longitudinal vortex behavior. Attention is given to Reynolds number sensitivities, vortex breakdown and interactions, vortex control on highly swept wings, and vortex control in juncture flows. R.E.P.

A93-18851 National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ADAPTIVE REMESHING FOR THREE-DIMENSIONAL COMPRESSIBLE FLOW COMPUTATIONS
J. PERAIRE, J. PEIRO (Imperial College of Science, Technology, and Medicine, London, United Kingdom), and K. MORGAN (Swansea Univ. College, United Kingdom) Journal of *Computational Physics* (ISSN 0021-9991) vol. 103, no. 2 Dec. 1992 p. 269-285. Research supported by NASA and Dassault Aviation refs
(Contract NAGW-478; NAGW-1809)
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A practical solution algorithm for steady 3D Euler flows is presented. This algorithm employs coupling of a surface triangulator, an automatic tetrahedral mesh generator, an unstructured grid flow solver, and an error estimation procedure. The performance of the method is illustrated using a shock

interaction problem in high Mach number flow over a swept circular cylinder. C.D.

A93-18855

A NEW LAGRANGIAN METHOD FOR STEADY SUPERSONIC FLOW COMPUTATION. II - SLIP-LINE RESOLUTION. III - STRONG SHOCKS

W. H. HUI and C. Y. LOH (Waterloo Univ., Canada) Journal of Computational Physics (ISSN 0021-9991) vol. 103, no. 2 Dec. 1992 p. 450-471. Research supported by NSERC refs
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It is shown that a first-order Godunov scheme based on a new Lagrangian formulate for steady supersonic flow always resolves an isolated slip-line discontinuity crisply, provided it is initially aligned with a grid line. It is demonstrated that a straightforward extension of Sweby's (1984) second-order scalar TVD scheme to the system of Euler equations in the new Lagrangian formulation, with no special procedure for slip-line detection, always resolves a slip-line in at most two points. Examples are given. Then, two special difficulties associated with computing steady supersonic flow where strong shocks are presented are studied. The first difficulty involves the well-posedness of the Cauchy problem and arises when the principle of domain of influence for the governing hyperbolic Euler equations is violated during marching. The second difficulty occurs when the shock is extremely strong so that the numerical errors due to Godunov averaging of flow within a cell containing the shock cause the Riemann problems to have no solution. C.D.

A93-19127

TOWARD AN INTEGRATION OF AERODYNAMICS AND AEROACOUSTICS OF ROTORS

L. MORINO and M. GENNARETTI (Rome I, Univ., Italy) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 11-18. Research supported by Italian Aerospace Research Center

The paper presents a new boundary integral formulation that is applicable for both aerodynamics and aeroacoustics. Specifically, the aerodynamic formulation allows one to obtain the pressure distribution over the surface of the body as well as other aerodynamic quantities. Having obtained these quantities, the same boundary integral representation may be used to solve the aeroacoustic problem, i.e., to evaluate the pressure in the field. The formulation is based on the assumption of potential flows, although an extension of the formulation to viscous flows is briefly outlined. The relationship between this formulation and different approaches available for aeroacoustics is also examined. Numerical results obtained with the proposed formulation are in good agreement with experimental data, for both aerodynamics and aeroacoustics. In addition, we present aeroacoustic results obtained with alternate aeroacoustic formulations which differ only by nonlinear terms; large discrepancies are observed between the various results. Reasons for these discrepancies are provided. Author

A93-19130

EXPERIENCE WITH BOUNDARY ELEMENT METHODS TO CALCULATE THE AERODYNAMIC CHARACTERISTICS OF AIRCRAFT

SIEGFRIED WAGNER (Stuttgart Univ., Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 29-38. refs

Some experiences with boundary element methods, specifically vortex-lattice techniques, are summarized to calculate the aerodynamic characteristics of fixed-wing and rotary-wing aircraft as well as wind turbines. A so-called field-panel technique for 2D flow is developed. This technie solves the full-potentia l equation iteratively by solving the Laplace equation by a panel method and the nonlinear part by a field technique. R.E.P.

A93-19132* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

ON THE COUPLING BETWEEN A SUPERSONIC BOUNDARY LAYER AND A FLEXIBLE SURFACE

ABDELKADER FRENDI (Analytical Services and Materials, Inc., Hampton, VA), LUCIO MAESTRELLO (NASA, Langley Research Center, Hampton, VA), and ALVIN BAYLISS (Northwestern Univ., Chicago, IL) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 46-55. Previously announced in STAR as N93-10757 refs
(Contract NAS1-19317; NAS1-18107; NAS1-18605)

The coupling between a two-dimensional, supersonic, laminar boundary layer and a flexible surface is studied using direct numerical computations of the Navier-Stokes equations coupled with the plate equation. The flexible surface is forced to vibrate by plane acoustic waves at normal incidence emanated by a sound source located on the side of the flexible surface opposite to the boundary layer. The effect of the source excitation frequency on the surface vibration and boundary layer stability is analyzed. We find that, for frequencies near the fifth natural frequency of the surface or lower, large disturbances are introduced in the boundary layer which may alter its stability characteristics. The interaction between a stable two-dimensional disturbance of Tollmien-Schlichting (TS) type with the vibrating surface is also studied. We find that the disturbance level is higher over the vrating flexible surface than that obtained when the surface is rig id, which indicates a strong coupling between flow and structure. However, in the absence of the sound source the disturbance level over the rigid and flexible surfaces are identical. This result is due to the high frequency of the TS disturbance which does not couple with the flexible surface. Author

A93-19133

EXPERIMENTS ON THE ACTIVE CONTROL OF BOUNDARY LAYER TRANSITION

P. A. NELSON, J.-L. RIOUAL, and M. J. FISHER (Southampton Univ., United Kingdom) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 56-62. Sponsorship: Research pported by Rolls-Royce, PLC refs

Experimental resu lts show that the streamwise location of transition in a flat plate boundary layer can be monitored by the measurement of surface pressure fluctuations. Furthermore it is shown that these pressure fluctuations can be used to maintain transition at a desired location further downstream via a control system which regulates boundary layer suction through a porous titanium sheet. The integral controller in the system shows great abilities to give to the system a fast and stable response in the presence of external disturbances. The prediction of stability made from the identification of the plant is in good agreement with experimental results. Author

A93-19134

IMPROVEMENT OF HIGH-AOA AIRFOIL STALLING PERFORMANCE BY INTERNAL ACOUSTIC EXCITATION

FEI-BIN HSIAO (Natnal Cheng Kung Univ., Tainan, Taiwan), RONG-NAN SHYU, and RYA C. CHANG (Chung Shan Inst. of Science and Technology, Taiching, Taiwan) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 63-71. refs
(Contract NSC-79-0210-D006-03)

The internal acoustic excitation techniques is successfully applied to improve the aerodynamic performance of a NACA 63(3)-018 cross section airfoil at high angle of attack (AOA). Tests are separately conducted in two suction, open-circuited wind tunnels for measurements and flow visualization at an operating Reynolds number 3.1 x 100,000 and 2.7 x 10,000 respectively. The experimental results indicate that for the low post-stalled airfoil performance at AOA = 18 to 24 deg, the leading-edge flow separation is delayed by excitation of a frequency near the shear

layer instability frequency, ft. However, if AOA is increased beyond 24 degs, flow separation from the leading edge of the airfl is unavoidable. In this case , the most effective frequency for improving the airfoil performance matches the vortex shedding frequency, fs, in the wake. Under effective excitation, the vortex flow takes place prematurely on the upper surface of the airfoil, resulting in both a higher lift and a higher drag due to decreasing base pressure over the upper surface of the airfoil. Author

A93-19135
ON SPACE CORRELATION OF PRESSURE PULSATIONS ON THE STREAMLINED SURFACE BEFORE A STEP
BORIS M. EFIMTSOV (TsAGI, Moscow, Russia) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 72-77. refs

The space correlation of spectral components of wall pressure pulsations produced by the 2D supersonic separation of turbulent and transient types is presented. The primary dimensionless parameter influence on a degree of the space pressure pulsation correlation over the entire interaction region is examined. Numerous characteristic peculiarities of the space field structure of the turbulent pressure pulsation separation along the coordinate in the flow direction and orthogonally to the flow are revealed. R.E.P.

A93-19144* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECTS OF A TRAILING EDGE FLAP ON THE AERODYNAMICS AND ACOUSTICS OF ROTOR BLADE-VORTEX INTERACTIONS
B. D. CHARLES, H. TADGHIGHI, and A. A. HASSAN (McDonnell Douglas Helicopter Co., Mesa, AZ) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 153-162. refs
(Contract NAS1-13169)

The use of a trailing edge flap on a helicopter rotor has been numerically simulated to determine if such a device can mitigate the acoustics of blade vortex interactions (BVI). The numerical procedure employs CAMRAD/JA, a lifting-line helicopter rotor trim code, in conjunction with RFS2, an unsteady transonic full-potential flow solver, and WOPWOP, an acoustic model based on Farassat's formulation 1A. The codes were modified to simulate trailing edge flap effects. The CAMRAD/JA code was used to compute the far wake inflow effects and the vortex wake trajectories and strengths which are utilized by RFS2 to predict the blade surface pressure variations. These pressures were then analyzed using WOPWOP to determine the high frequency acoustic response at several fixed observer locations below the rotor disk. Comparisons were made with different flap deflection amplitudes and rates to assess flap effects on BVI. Numerical experiments were carried out using a one-seventh scale AH-1G rotor system for flight conditions simulating BVI encountered during low speed descending flight with and without flaps. Predicted blade surface pressures and acoustic sound pressure levels obtained have shown good agreement with the baseline no-flap test data obtained in the DNW wind tunnel. Numerical results indicate that the use of flaps is beneficial in reducing BVI noise. Author

A93-19150
TECHNICAL PROSPECTS FOR COMPUTATIONAL AEROACOUSTICS
P. L. ROE (Michigan Univ., Ann Arbor) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 206-213. refs

An overview is presented that summarizes the early work accomplished in the new field of computational aeroacoustics. Attention is given to discretization techniques, linear and nonlinear aerodynamic codes, and boundary conditions. It is suggested that a strategy should be adopted to use very simple boundary conditions, but to refine the mesh close to boundaries as well as in other critical regions of the flow. R.E.P.

A93-19151* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DISPERSION-RELATION-PRESERVING SCHEMES FOR COMPUTATIONAL AEROACOUSTICS
CHRISTOPHER K. W. TAM and JAY C. WEBB (Florida State Univ., Tallahassee) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 214-222. refs
(Contract NAG3-1267; N00014-89-J-1836)

Finite difference schemes that have the same dispersion relations as the original partial differential equations are referred to as dispersion-relation-preserving (DRP) schemes. A method to construct time marching DRP schemes by optimizing the finite difference approximations of the space and time derivatives in the wave number and frequency space is presented. A sequence of numerical simulations is then performed. R.E.P.

A93-19158
FLOW FIELD MEASUREMENTS IN A TURBULENT FREE JET ISSUING FROM A SHARP-EDGED SQUARE SLOT
W. R. QUINN (St. Francis Xavier Univ., Antigonish, Canada) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 287-294. Research supported by NSERC refs

Results of an experimental study of a turbulent free jet of air issuing from a sharp-edged square slot into still air surroundings are presented. The quantities measured directly, using hot-wire anemometry, include: the three components of the mean velocity vector, the three Reynolds normal stresses and the two Reynolds primary shear stresses. It was found that the near flow field of the jet is dominated by four sets of counterrotating streamwise vortices. These vortices, which represent Prandtl's secondary flow of the first kind, are generated from distributed vorticity shed from the four corners of the slot by skewing of the shear layers as a result of the vena contracta effect. Also, mean streamwise velocity off-center peaks were found in the very near flow field; such mean streamwise velocity off-center peaks may be the result of the self-induction of the streamwise vortices. Author

A93-19194* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STREAMLINE CURVATURE IN SUPERSONIC SHEAR LAYERS
V. KIBENS (McDonnell Douglas Research Labs., Saint Louis, MO) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 655-662. refs
(Contract NAS1-19060)

Results of an experimental investigation in which a curved shear layer was generated between supersonic flow from a rectangular converging/diverging nozzle and the freestream in a series of open channels with varying radii of curvature are reported. The shear layers exhibit unsteady large-scale activity at supersonic pressure ratios, indicating increased mixing efficiency. This effect contrasts with supersonic flow in a straight channel, for which no large-scale vortical structure development occurs. Curvature must exceed a minimum level before it begins to affect the dynamics of the supersonic shear layer appreciably. The curved channel flows are compared with reference flows consisting of a free jet, a straight channel, and wall jets without sidewalls on a flat and a curved plate. C.A.B.

A93-19219
UNSTEADY PRESSURES ON EXHAUST NOZZLE INTERIOR SURFACES - EMPIRICAL CORRELATIONS FOR PREDICTION
M. SALIKUDDIN (GE Aircraft Engines, Cincinnati, OH) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 873-881. refs

Scale model tests were conducted to measure the aerodynamic performance and internal surface unsteady pressures of rectangular convergent-divergent (2D-CD) nozzles with a fixed throat area. Straight divergent flaps were used in these nozzles. The area ratio (i.e., exit area/throat area) was varied by altering the flap divergence angle. Static and unsteady pressure data were acquired simultaneously along the centerline and at various transverse locations on one of the nozzle flaps. Tests were conducted for each configuration over a range of nozzle pressure ratios, including over-expansion conditions which generated shocks inside the nozzles. Data from these tests are utilized in developing empirical correlations between the nozzle interior wall unsteady pressure and the mean flow parameters for different flow regimes. Using these empirical correlations, both overall and spectral unsteady pressure levels for attached subsonic/supersonic turbulent boundary layers, as well as, separated turbulent boundary layers including shock/boundary-layer interactions can be predicted. Author

A93-19221* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FORWARD ROTOR VORTEX EFFECTS ON COUNTER ROTATING PROPELLER NOISE
MICHELE LAUR, BECKY SQUIRES, and ROBERT T. NAGEL (North Carolina State Univ., Raleigh) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 890-897. Research supported by McDonnell Douglas Corp. and General Electric Co. refs
(Contract NAG3-855)

Three configurations of a model counter rotating propeller manipulate the blade tip flow by: placing the CRP at angle of attack, installing shrouds, and turning the upstream blades to provide forward sweep. Flow visualization and flow measurements with thermal anemometry show no evidence of a tip vortex; however, a leading edge vortex was detected on aft swept blades. The modifications served to alter the strength and/or path of the leading edge vortex. The vortical flow is eliminated by forward sweep on the upstream propeller blades. Far field acoustic data from each test indicate only small influences on the level and directivity of the BPFs. The interaction tone at the sum of the two BPF's was significantly altered in a consistent manner. As the vortex system varied, the interaction tone was affected: far field noise levels in the forward quadrant increased and the characteristic noise minimum near the plane of rotation became less pronounced and in some cases were eliminated. If the forward propeller leading edge vortex system does not impact the rear propeller in the standard manner, a net increase in the primary interaction tone occurs for the model tested. If the leading edge vortex is removed, the interaction tone increases. Author

A93-19222
AN ASSESSMENT OF WAKE STRUCTURE BEHIND FORWARD SWEPT AND AFT SWEPT PROPFANS AT HIGH LOADING
P. LAVRICH, J. SIMONICH, D. MCCORMICK (United Technologies Research Center, East Hartford, CT), and D. PARZYCH (Hamilton Standard, Windsor Locks, CT) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 898-906. Research supported by United Technologies Research Center refs
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An experimental study was performed to measure the vortical wakes from propfan configurations run with both aft swept and forward swept blading. A comparison of the wake structure was made between the two configurations at three loading conditions. Flow visualization indicated a leading edge vortex exists on the aft swept blading which had previously been identified as a nominant interaction noise mechanism. In contrast, the forward swept blading exhibited a leading edge flow separation which did not form a vortex. Differences in the tip vortex structure were exhibited and were attributed to the presence or absence of a leading edge vortex. The tip vortex of the forward swept blade had much less core velocity deficit than the aft swept wake. It was observed that the forward swept configuration requires additional blade sweep at the leading edge to induce a leading edge vortex. Author

A93-19276
SHOCK FORMATION IN OVEREXPANDED TIP LEAKAGE FLOW
JOHN MOORE (Virginia Polytechnic Inst. and State Univ., Blacksburg) and KEVIN M. ELWARD (General Electric Co., Schenectady, NY) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Rolls-Royce, PLC and Virginia Polytechnic Inst. and State Univ refs
(ASME PAPER 92-GT-1)

Shock formation due to overexpansion of supersonic flow at the inlet to the tip clearance gap of a turbomachine has been studied. The flow was modeled on a water table using a sharp-edged rectangular channel. The flow exhibited on oblique hydraulic jump starting on the channel sidewall near the channel entrance. This flow was analyzed using hydraulic theory. The results suggest a model for the formation of the jump. The hydraulic analogy between free surface water flows and compressible gas flows is used to predict the location and strength of oblique shocks in analogous tip leakage flows. Features of the flow development are found to be similar to those of compressible flow in sharp-edged orifices. Possible implications of the results for high-temperature gas turbine design are considered. Author

A93-19277
RECENT ADVANCES IN SIMULATING UNSTEADY FLOW PHENOMENA BROUGHT ABOUT BY PASSAGE OF SHOCK WAVES IN A LINEAR TURBINE CASCADE
J. C. COLLIE, H. L. MOSES, J. A. SCHETZ (Virginia Polytechnic Inst. and State Univ., Blacksburg), and B. A. GREGORY (GE Aircraft Engines, Cincinnati, OH) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-4)

The Virginia Tech Wind Tunnel Transonic Cascade Facility (Bertsch, 1990; Doughty, 1991) was modified to enable investigations of unsteady flow phenomena induced by the passage of shock waves. Shock waves in a linear turbine cascade were generated by a shotgun blast upstream of the blade row, and shadowgraph photographs and high-response pressure data were analyzed. Results are compared with previously published experimental results and numerical predictions. I.S.

A93-19278
A STATISTICAL APPROACH TO THE EXPERIMENTAL EVALUATION OF TRANSONIC TURBINE AIRFOILS IN A LINEAR CASCADE
M. L. SHELTON, B. A. GREGORY (GE Aircraft Engines, Cincinnati, OH), R. L. DOUGHTY, T. KISS, and H. L. MOSES (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-5)

Three different transonic turbine airfoils (the baseline, the low unguided turning, and the unloaded trailing edge designs) were tested in the Virginia Polytechnic Institute and State University Transonic Cascade Facility, and quantitative differences between the three airfoils were evaluated using a statistical approach. The study illustrated the difficulties in measuring small, but still significant, differences in airfoil efficiency, particularly for transonic and supersonic flow, and demonstrated the ability of the statistical approach to assess measured differences relative to the variation in the process. The study also assessed the degree of confidence in the transonic testing process at the cascade facility. I.S.

A93-19291
AERODYNAMIC PERFORMANCE OF A TRANSONIC LOW ASPECT RATIO TURBINE NOZZLE

S. H. MOUSTAPHA (Pratt & Whitney Canada, Montreal), W. E. CARSCALLEN (National Research Council of Canada, Ottawa), and J. D. MCGEACHY (Queen's Univ., Kingston, Canada) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-31)

This paper presents detailed information on the three-dimensional flow field in a realistic turbine nozzle with an aspect ratio of 0.65 and a turning angle of 76 degrees. The nozzle has been tested in a large scale planar cascade over a range of exit Mach numbers from 0.3 to 1.3. The experimental results are presented in the form of nozzle passage Mach number distributions and spanwise distribution of losses and exit flow angle. Details of the flow field inside the nozzle passage are examined by means of surface flow visualization and Schlieren pictures. The performance of the nozzle is compared to the data obtained for the same nozzle tested in an annular cascade and a stage environment. Excellent agreement is found between the measured pressure distribution and the prediction of a 3D Euler flow solver. Author

A93-19292
INVESTIGATION OF COMPRESSOR ROTOR WAKE STRUCTURE AT PEAK PRESSURE RISE COEFFICIENT AND EFFECTS OF LOADING
J. PRATO and B. LAKSHMINARAYANA (Pennsylvania State Univ., University Park) Jun. 1992 15 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-32)

An experimental study of the 3D characteristics of the mean velocity in the trailing-edge, near-wake and far-wake regions of a highly loaded low-speed compressor rotor is presented. The wake structure and decay characteristics are compared with the wake data in the same compressor with moderate loading. Variations in the axial, radial and tangential components of mean velocity at various radial and axial locations are derived from the data and compared with previous data at lower loading to determine the effects of loading. R.E.P.

A93-19293
PRESSURE FLUCTUATION ON CASING WALL OF ISOLATED AXIAL COMPRESSOR ROTORS AT LOW FLOW RATE
MASAHIRO INOUE, MOTOO KUROUMARU, and YOUCHI ANDO (Kyushu Univ., Fukuoka, Japan) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by MOESC and Harada Memorial Foundation refs
(ASME PAPER 92-GT-33)

The pressure fluctuations on the casing wall of two axial flow compressor rotors with various tip clearances have been analyzed by the use of two kinds of correlation functions. Behavior of the pressure fluctuation varies depending on tip clearance and blade solidity. In the case of small tip clearance, the nature of disturbances becomes random as the flow rate is reduced to a stall condition. For moderate tip clearance, coherent-structured disturbances appear intermittently at low flow rate. They appear more frequently as the solidity is increased and the flow rate becomes lower. For large tip clearance, the coherent structured disturbances exist even at considerably higher flow rates. Corresponding to these features there are peculiar patterns in the correlation designed as 'phase-locked correlation function'. Author

A93-19294
BLADE LOADING AND SHOCK WAVE IN A TRANSONIC CIRCULAR CASCADE DIFFUSER
H. HAYAMI (Kyushu Univ., Kasuga, Japan), M. SAWAE (Nippon Mining Co., Ltd., Chita, Japan), T. NAKAMURA (Toshiba Co., Yokohama, Japan), and N. KAWAGUCHI (Kyushu Univ., Kasuga, Japan) Jun. 1992 5 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract MOESC-01550151)
(ASME PAPER 92-GT-34)

Low-solidity circular cascade, conformally transformed from high-stagger linear cascade of double-circular-arc vanes with solidity 0.69, was tested as a part of diffuser systems of a transonic centrifugal compressor and the static pressures were measured around a vane of the cascade and on the side wall between cascade vanes in detail. The blade loading of cascade vane was discussed by integrating the pressure distribution around the vane. The experimental data for lift-coefficient of vane were almost on a single straight line with positive gradient against angle-of-attack over a wide range of inflow Mach number and inflow angle. The maximum lift-coefficient reached about 1.5 and the vane worked well to the surge condition of the compressor. The structure of shock wave was also discussed by drawing a contour map of flow Mach number between cascade vanes. The normal shock wave was observed on the suction surface of vane and it moved upstream along the suction surface with the decrease in inflow angle. The vane did not fall in stall even though the Mach number upstream of the shock wave was over 1.4. Author

A93-19296
RECESS VANE PASSIVE STALL CONTROL
M. ZIABASHARHAGH, A. B. MCKENZIE, and R. L. ELDER (Cranfield Inst. of Technology, United Kingdom) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Rolls-Royce, PLC refs
(ASME PAPER 92-GT-36)

An experimental investigation has been carried out on the influence of a vaned recessed casing treatment on the stall margin improvement of axial flow fans with different hub to tip ratio, with and without inlet distortion. The inlet distortion tests were conducted on a 0.5 hub to tip ratio fan and significant increases in the flow range with only small drops in operating efficiency were observed. The clean flow tests were conducted on higher hub to tip ratio fans (0.7 and 0.9). In each case the stage characteristic was compared with the results obtained with a solid casing. Significant increases in the flow range, with only modest or no loss in operating efficiency, were observed for optimum configurations at both diameter ratios. Author

A93-19301
VISCOUS FLOWS IN CENTRIFUGAL COMPRESSOR DIFFUSERS AT TRANSONIC MACH NUMBERS
I. TEIPEL, A. WIEDERMANN, and W. EVERS (Hannover, Univ., Hanover, Germany) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-48)

Results of a numerical investigation of steady 2D and 3D flow fields in vaned diffusers of highly loaded centrifugal compressors are presented. The explicit MacCormack scheme (1981) is used to calculate inviscid and viscous effects because of the possibility of vectorization. Transonic Mach numbers are reached in the entrance of the diffuser and therefore time-dependent equations are solved. Two methods are employed to accelerate convergence of this explicit scheme: local time stepping and the application of a multigrid scheme. The numerical procedure is used to compute 2D transonic flow fields of a centrifugal compressor diffuser at different impeller speeds. It is shown that the predicted pressure field is in reasonable agreement with experimental data. An evaluation of the complete 3D Navier-Stokes equations is also presented. C.A.B.

A93-19302
AN INVESTIGATION ON THE ARTIFICIAL VISCOSITY IN THE TRANSONIC STREAM FUNCTION FORMULATION
J. Z. XU, J. Y. DU, H. SHEN, and M. C. GE (Chinese Academy of Sciences, Inst. of Engineering Thermophysics, Beijing, China) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine

Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-49)

A theoretical study of the artificial density method applied in the transonic potential and stream function calculations is presented. It is shown that the analysis method is no longer valid in the stream function formulation, and a correct expression for the artificial viscosity in the stream function technique is derived. The numerical cases indicate that the computed range of Mach number by the present transonic stream function formulation is extended and the shock location is closer to the experimental result. R.E.P.

A93-19309
MODIFIED SURGE IN AN AXIAL FLOW COMPRESSOR
LIBOR PUST (National Research Inst. for Machine Design, Prague, Czechoslovakia) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-59)

This paper deals with an experimental study of the unsteady flow in a multistage axial-flow compressor with a high design flow coefficient (Pi = 1.2) at rpm lower than the design ones. A detailed description of the rotating stall during the so-called 'modified surge' is given. In this surge type the rotating stall exists during all the surge cycle, in contradistinction of classic surge, when the rotating stall exists only in a part of the surge cycle. Author

A93-19310
TURBULENCE EVALUATION WITHIN THE SECONDARY FLOW REGION OF A TURBINE CASCADE
D. G. GREGORY-SMITH and TH. BIESINGER (Durham Univ., United Kingdom) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Rolls-Royce, PLC refs
(ASME PAPER 92-GT-60)

Three-dimensional turbulent and mean velocity fields have been measured within a large-scale axial turbine cascade. The results indicate a complex turbulent flow field especially within the secondary vortex. The turbulence is shown to be significantly nonisotropic, and the production and dissipation terms in the turbulent kinetic energy equation have been evaluated in order to illustrate the unusual turbulence behavior. Comparisons with a Navier-Stokes computation indicate areas for improvement in turbulence and transition modeling. Author

A93-19311
THREE DIMENSIONAL TRANSONIC FLOW MEASUREMENTS IN AN AXIAL TURBINE WITH CONICAL WALLS
F. KOST (DLR, Inst. fuer Experimentelle Stroemungsmechanik, Goettingen, Germany) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-61)

To investigate the spatial flow structure caused by sweep and dihedral effects in turbo machinery blade rows, detailed measurements have been conducted in the windtunnel for rotating annular cascades of DLR-Goettingen. The special configuration investigated, consisted of a turbine rotor equipped with straight blades, a conical hub and a conical casing with a cone half-angle of 30 deg. Numerous flow data are obtained from surface pressure distributions at seven radial blade sections and from Laser velocimetry upstream, down-stream and inside and rotor. As the laser-two-focus technique is a two-dimensional one, two laser velocity measurements at different angles had to be taken at each measurement location in the flow, in order to get the three components of velocity. The measurement accuracy of the three derived Mach number components in the blade relative system has been evaluated and stored together with mean and fluctuating values at each measurement location. Author

A93-19312
SECONDARY FLOWS IN A TRANSONIC CASCADE - VALIDATION OF A 3-D NAVIER-STOKES CODE
F. BASSI (Milano, Politecnico, Milan, Italy) and M. SAVINI (CNR, CNPM, Peschiera Borromeo, Italy) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-62)

In this work is presented a finite volume full 3D Navier-Stokes solver suitable for turbulent turbomachinery computations. The code is applied to the analysis of the secondary flow patterns in a transonic turbine cascade at three different isentropic outlet Mach numbers; namely 0.50, 1.02, 1.38. Detailed measurements obtained in four planes downstream of the trailing edge allow for comparison of losses, flow angles, vorticity and hence for a deep evaluation of the accuracy of the numerical results. Moreover the code is used to gain insight into the formation and the evolution of secondary flows inside the blade passage, into the generation of losses and into characteristic feature of these flows hard to detect experimentally. All the above mentioned aspects are examined and discussed as well as the influence of compressibility, giving thus a precise picture of secondary flows in the transonic regime. Author

A93-19313
ASSESSMENT OF A 3-D EULER CODE FOR SUBSONIC TURBINE VANE FLOWS AND STUDY OF THE NON RADIAL BLADE STACKING
J. VIALONGA, B. PETOT (SNECMA, Moissy-Cramayel, France), and THIERRY CHIAPPA (Nancy, Ecole Nationale Superieure des Mines, France) Jun. 1992 14 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by DRET and Service Technique des Programmes Aeronautiques refs
(ASME PAPER 92-GT-63)

A 3D code for the prediction of steady inviscid compressible flows in turbine vane cascades is evaluated. The application of this tool to the study of 3D inviscid effects due to nonradial stacking of airfoils is also described. The numerical method associated with an original 3D grid generator is examined. Several computational results with different inlet stagnation pressure profiles are compared to full-scale cascade test measurements in the case of a low-pressure turbine vane. The convection of the upstream vorticity induced by the total pressure profile and its influence on exit flow angle are demonstrated, and they are used to evaluate part of the secondary flows in low-pressure turbine vanes. Once the accuracy of the computed flow field is sufficiently confirmed, the 3D Euler code is used to evaluate the influence of nonradial blade stacking on 3D inviscid flows. As expected, the influence on spanwise pressure distribution is marked, and best results in terms of endwall aerodynamics improvement are obtained with the bowed vane. C.A.B.

A93-19314
AN INVESTIGATION OF SPANWISE MIXING IN MULTISTAGE AXIAL FLOW COMPRESSORS
S.-M. LI and M.-Z. CHEN (Beijing Univ. of Aeronautics and Astronautics, China) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-64)

An equation system has been deduced for meridional throughflow fields of multistage axial flow compressors, presenting different kinds of spanwise mixing effects of the fields in a unified form. The spanwise mixing in compressors is caused by three kinds of effects, molecular motion, turbulent diffusion, and circumferential nonuniformities, the last of which includes secondary flow effects and others. This equation system thus unifies the two models for spanwise mixing analyses by Adkins and Smith (1981) and Gallimore and Cumpsty (1986). The turbulent diffusion in the 2D meridional fields is determined by complex 3D shear flows in compressors, rather than the 2D shearing alone, so a turbulence model for 2D meridional flow calculations is proposed on the basis

of a simplified 3D shearing structure in compressors. The circumferentially non-uniform correlation terms in the equation system have been modeled on the basis of Adkins and Smith (1981) secondary flow model and the experimental data for annular cascade wakes. The results obtained agree well with the experiments for five compressors. Author

A93-19321
COMPRESSIBLE FLOW PRESSURE LOSSES IN WYE-JUNCTIONS
N. I. ABOU-HAIDAR and S. L. DIXON (Leicester Univ., United Kingdom) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-71)
The compressible flow pressure losses in sharp cornered wye-junctions with symmetrical branches under dividing and combining flow conditions are considered. The additional total pressure losses occurring in flow through several three-leg junctions, using dry air as the working fluid, are determined experimentally. Results covering a wide speed range up to choking are presented for three different wye-junction geometries. Separate flow visualization Schlieren tests detected the presence of normal shock waves, located at up to one duct diameter downstream of the junction, and therefore confirmed the choking of the flow at the vena contracta. The highest attainable Mach number (M3) of the averaged whole flow was 0.9 for one of the dividing flow geometries and 0.65 for several of the combining flow cases. In general, the compressible flow loss coefficients, caused by the presence of the wye-junctions, can be expected to be higher for dividing flows and lower for combining flows than would be the case for incompressible flows because of the influence of Mach number (M3) on the magnitude of the denominator. C.A.B.

A93-19322* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AEROLOADS AND SECONDARY FLOWS IN A TRANSONIC MIXED FLOW TURBINE STAGE
K. R. KIRTLEY, T. A. BEACH (Sverdrup Technology, Inc.; NASA, Lewis Research Center, Cleveland, OH), and CASS ROGO (Teledyne CAE, Toledo, OH) Jun. 1992 13 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract NAS3-25266)
(ASME PAPER 92-GT-72)
A numerical simulation of a transonic mixed flow turbine stage has been carried out using an average passage Navier-Stokes analysis. The mixed flow turbine stage considered here consists of a transonic nozzle vane and a highly loaded rotor. The simulation was run at the design pressure ratio and is assessed by comparing results with those of an established throughflow design system. The three-dimensional aerodynamic loads are studied as well as the development and migration of secondary flows and their contribution to the total pressure loss. The numerical results indicate that strong passage vortices develop in the nozzle vane, mix out quickly, and have little impact on the rotor flow. The rotor is highly loaded near the leading edge. Within the rotor passage, strong spanwise flows and other secondary flows exist along with the tip leakage vortex. The rotor exit loss distribution is similar in character to that found in radial inflow turbines. The secondary flows and non-uniform work extraction also tend to significantly redistribute a non-uniform inlet total temperature profile by the exit of the stage. Author

A93-19324* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AERODYNAMIC DESIGN OF TURBOMACHINERY BLADING IN THREE-DIMENSIONAL FLOW - AN APPLICATION TO RADIAL INFLOW TURBINES
Y. L. YANG, C. S. TAN, and W. R. HAWTHORNE (MIT, Cambridge, MA) Jun. 1992 13 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by U.S. Army refs
(Contract NAG3-772)
(ASME PAPER 92-GT-74)
A computational method, based on a theory for turbomachinery blading design in three-dimensional inviscid flow, is applied to a parametric design study of a radial inflow turbine wheel. As the method requires the specification of swirl distribution, a technique for its smooth generation within the blade region is proposed. Excellent agreements have been obtained between the computed results from this design method and those from direct Euler computations, demonstrating the correspondence and consistency between the two. The computed results indicate the sensitivity of the pressure distribution to a lean in the stacking axis and a minor alteration in the hub/shroud profiles. Analysis based on Navier-Stokes solver shows no breakdown of flow within the designed blade passage and agreement with that from design calculation; thus the flow in the designed turbine rotor closely approximates that of an inviscid one. These calculations illustrate the use of a design method coupled to an analysis tool for establishing guidelines and criteria for designing turbomachinery blading. Author

A93-19333
SURFACE-CURVATURE-DISTRIBUTION EFFECTS ON TURBINE-CASCADE PERFORMANCE
THEODOSIOS KORAKIANITIS and PASCHALIS PAPAGIANNIDIS (Washington Univ., Saint Louis, MO) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-84)
The manufacturing accuracy of turbine blades is judged by the difference between designed and produced location of each point around the airfoils. This paper shows that the design-point and off-design-point aerodynamic and heat transfer performance of turbine cascades is affected significantly by the distribution of curvature along the suction and pressure surfaces, and less significantly by the exact location of each one point. The performance of turbine blades designed with continuous slope of curvature distribution, and with slight discontinuities in the slope of curvature, are examined using a computer program for various design and off-design flow conditions. The accuracy of the computations is checked by comparison of computational results with cascade solutions of known experimental output. It is concluded that the accuracy in local curvature is just as important as the design-location-by-manufactured-location accuracy of each point on the blade. Author

A93-19334
A STUDY OF STALL IN A LOW HUB/TIP RATIO FAN
M. SOUNDRANAYAGAM (National Engineering Lab., Glasgow, United Kingdom) and R. L. ELDER (Cranfield Inst. of Technology, United Kingdom) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-85)
Results of an investigation carried out in order to define the process of rotating stall inception in a low-speed low-hub-tip ratio fan are presented. The analysis considers the effect of streamtube contraction which has been studied theoretically, and real flow effects which have been studied experimentally. The study of streamtube contraction indicates that the root rematches to a more stable operating point, thus alleviating some of the problems in that region. Real fluid effects tended to steepen the root pressure rise characteristic, thus enhancing the stability in that region. Hot wire flow mapping at the rotor exit supported the overall conclusion that the rotor showed a strong reluctance to stall at the root, apparently due to 'centrifuging' of the boundary layer toward the tip. C.A.B.

A93-19336
EXPERIMENTAL ANALYSIS OF TRANSONIC FLOW THROUGH THE VARIABLE NOZZLE OF A RADIAL INFLOW TURBINE
H. E. GALLUS, U. LINGNER (Aachen, Rheinisch-Westfaelische

Technische Hochschule, Germany), and I. ISPAS (Atlas Copco Energas Co., Cologne, Germany) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Atlas Copco Energas Co refs
(ASME PAPER 92-GT-90)

An experimental study has been conducted of the flow field in a transonic radial nozzle cascade, using an air test rig with variable nozzle vanes derived from an industrial radial-inflow turbine. Attention was given to this flow in the absence of a rotor; static pressure distributions have been measured on the vane pressure and suction sides and on the shroud endwall. Results are presented for various pressure ratios and nozzle-setting angles, and these are compared with numerical calculations for inviscid flow based on the 2D Euler equations. O.C.

A93-19337
INFLUENCE OF BLADE AERODYNAMIC LOADING ON EFFICIENCY OF RADIAL-INFLOW TURBINES
T. TAKAMURA and F. NISHIGUCHI (Nissan Motor Co., Ltd., Central Engineering Labs., Yokosuka, Japan) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-91)

This paper describes the relation between turbine efficiency and rotor blade loading parameters. Tests were carried out on 12 kinds of rotors, which had the same inlet velocity triangle and meridional contour, but different blade numbers (8-11) and blade lengths. The momentum thickness and shape factor of the boundary layers obtained from the results of a quasi-three-dimensional flow analysis were used as the rotor blade loading parameters. It was found that blade loading could be evaluated by the shape factor at the mean stream surface and that turbine efficiency was affected by the blade shape of the exducer. Author

A93-19361
ANALYSIS OF STEADY AND UNSTEADY TURBINE CASCADE FLOWS BY A LOCALLY IMPLICIT HYBRID ALGORITHM
C. J. HWANG and J. L. LIU (National Cheng Kung Univ., Tainan, Taiwan) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-127)

For the 2D steady and unsteady turbine cascade flows, the Euler/Navier-Stokes equations with Baldwin-Lomax turbulence model are solved in the Cartesian coordinate system. A locally implicit hybrid algorithm on the mixed type of meshes is utilized, where the convective dominated part in the flowfield is investigated by TVD scheme to acquire high-resolution results on the triangular elements, and the second- and fourth-order dissipative model is introduced on the O-typed quadrilateral grid in the viscous dominated area to minimize the numerical dissipation. It is determined that the unsteady aerodynamic behaviors are strongly dependent on the wake/shock/boundary layer interactions. R.E.P.

A93-19362
AN INVISCID-VISCOUS INTERACTION APPROACH TO THE CALCULATION OF DYNAMIC STALL INITIATION ON AIRFOILS
T. CEBECI (California State Univ., Long Beach), M. F. PLATZER (U.S. Naval Postgraduate School, Monterey, CA), H. M. JANG, and H. H. CHEN (California State Univ., Long Beach) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract AF-AFOSR-90-0262)
(ASME PAPER 92-GT-128)

An interactive boundary-layer method is described for computing unsteady incompressible flows over airfoils, including the initiation of dynamic stall. The inviscid unsteady panel method developed by Platzer and Teng is extended to include viscous effects. The solutions of the boundary-layer equations are obtained with an inverse finite-difference method employing an interaction law based on the Hilbert integral, and the algebraic eddy-viscosity formulation of Cebeci and Smith. The method is applied to airfoils subject to periodic and ramp-type motions and its abilities are examined for a range of angles of attack, reduced frequency and pitch rate. Author

A93-19368
CALCULATION OF THREE-DIMENSIONAL UNSTEADY FLOWS IN TURBOMACHINERY USING THE LINEARIZED HARMONIC EULER EQUATIONS
KENNETH C. HALL and CHRISTOPHER B. LORENCE (Duke Univ., Durham, NC) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by GE Aircraft Engines refs
(ASME PAPER 92-GT-136)

An efficient three-dimensional Euler analysis of unsteady flows in turbomachinery is presented. The unsteady flow is modeled as the sum of a steady or mean flow field plus a harmonically varying small perturbation flow. The linearized Euler equations, which describe the small perturbation unsteady flow, are found to be linear, variable coefficient differential equations whose coefficients depend on the mean flow. A pseudo-time time-marching finite-volume Lax-Wendroff scheme is used to discretize and solve the linearized equations for the unknown perturbation flow quantities. Local time stepping and multiple-grid acceleration techniques are used to speed convergence. For unsteady flow problems involving blade motion, a harmonically deforming computational grid which conforms to the motion of the vibrating blades is used to eliminate large error-producing extrapolation terms that would otherwise appear in the airfoil surface boundary conditions and in the evaluation of the unsteady surface pressure. Results are presented for both linear and annular cascade geometries, and for the latter, both rotating and nonrotating blade rows. Author

A93-19380
PROFILE LOSSES OF AN ANNULAR TURBINE CASCADE IN UNSTEADY PERIODIC FLOW
M. LISAL, P. SOCH, and J. VRATNY (Czech Technical Univ., Prague, Czechoslovakia) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-153)

An experimental study of aerodynamic characterizations of an annular turbine cascade in an unsteady flow with the constant mean value, i.e., characteristic flow of turbomachinery, is presented. Results of measurements of steady profile losses in the Tu-2 axial annular turbine cascade, which is used in the Czechoslovak aircraft industry, are reported for cases in the range from -10 to 20 deg and for Reynolds numbers from 60,000 to 150,000. Measurements of unsteady profile losses in the turbine cascade, i.e., measurements with an upstream rotating rotor of prismatic blades, were taken at nearly identical conditions as those in the case without the rotor. A comparison of the profile losses in the unsteady flow with the profile losses in the steady flow is presented. P.D.

A93-19382
BOUNDARY LAYER EFFECTS ON THE TRANSONIC FLOW IN A STRAIGHT TURBINE CASCADE
M. STASTNY (Skoda, Plzen, Czechoslovakia) and P. SAFARIK (Czechoslovak Academy of Sciences, Inst. of Thermomechanics, Prague, Czechoslovakia) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-155)

The paper analyzes two subjects related to the transonic flow in a straight turbine cascade, namely, turbulization of the suction side boundary layer and its subsequent development along the profile, and the influence of side wall boundary layers on cascade flows. The turbulization effect of supersonic compression on the

boundary layers which accompany transonic expansion on the suction side of the profile is investigated by independent methods. Both the experimental results and the calculation confirm the loss of stability of the laminar boundary layer and its subsequent transition into turbulence in the region of an adverse pressure gradient. The possibility of reverse transition of the turbulent boundary layer in a subsequent strong favorable pressure gradient is investigated. P.D.

A93-19383
UNSTEADY PRESSURE MEASUREMENTS ON THE ROTOR OF A MODEL TURBINE STAGE IN A TRANSIENT FLOW FACILITY
A. J. DIETZ and R. W. AINSWORTH (Oxford Univ., United Kingdom) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Rolls-Royce, PLC and SERC refs
(ASME PAPER 92-GT-156)

This paper describes unsteady pressure measurements made on the mid span suction and pressure surfaces of a rotating turbine blade in a transient facility. The measurements were made at the engine representative conditions for this turbine using high spatial density surface mounted semi-conductor transducers. This high spatial density, coupled with the wide bandwidth capability of the sensors and data acquisition system, has enabled analyses of unsteady wave propagation effects (both in magnitude and phase) to be carried out. This paper significantly adds to the body of data available at engine representative conditions, particularly in terms of compressibility. Distinctions are drawn between events which are propagating at free stream velocities and those which move at local acoustic velocities. Comparisons are made with theories which have been previously expounded, and some inconsistencies are outlined. Author

A93-19384
TECHNIQUES FOR AERODYNAMIC LOSS MEASUREMENT OF TRANSONIC TURBINE CASCADES WITH TRAILING-EDGE REGION COOLANT EJECTION
D. J. MEE (Oxford Univ., United Kingdom) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Rolls-Royce, PLC refs
(ASME PAPER 92-GT-157)

Experimental techniques associated with the measurement of loss of transonic turbine blades with trailing-edge region coolant ejection are considered. Results from experiments with different coolant to free stream gas density ratios indicate that it is not always adequate to simulate only the coolant blowing rate. However, for the measurement of loss, the present experimental results indicate that it may be adequate to simulate the momentum flux ratio. In loss calculations the value used for the total pressure of the coolant gas is discussed and shown to influence a comparison of different cooling geometries. Author

A93-19385
TRANSONIC FLOW THROUGH TURBINE CASCADES WITH NONUNIFORM PITCH
R. KURZ (Univ. of the Federal Armed Forces, Hamburg, Germany) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research sponsored by BMVg refs
(ASME PAPER 92-GT-158)

The flow behind linear turbine cascades with uniform and nonuniform pitches was investigated both theoretically and experimentally. A calculation procedure based on an Euler-code for nonuniform pitch to chord ratios is presented. Experimental data were obtained by using a Laser-2-Focus measurement system and and Kiel probes. Outlet Laval numbers range from 0.7 to 1.0, corresponding to Reynolds numbers from 380,000 to 700,000. The pitch-to-chord ratio of the investigated configurations reaches from 0.771 to 0.877. Author

A93-19388
VISCOUS INTERACTION UPSTREAM AND DOWNSTREAM OF A TURBINE STATOR CASCADE WITH A PERIODIC WAKE FIELD
VERNON E. MCFARLAND and WILLIAM G. TIEDERMAN (Purdue Univ., West Lafayette, IN) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by USAF refs
(ASME PAPER 92-GT-162)

The influence of periodic rotor wakes has a substantial effect on the flow in a turbine stator cascade. A mechanism located upstream of a linear, low-aspect ratio, turbine cascade simulated wakes shed from rotor blades by translating cylindrical rods across the inlet of the cascade. In order to provide a test case to increase our fundamental understanding of the unsteady viscous flow typical of a gas turbine engine, three components of velocity, phased-locked into sixteen time windows which encompassed the rotor period, were measured at two upstream planes and one downstream plane. Due to the effects in the endwall region, the wake in the inlet plane bows in the tangential direction as the wake translates into the passage. The effects of the passage vortex do not decay significantly within one chord downstream of the exit of the cascade. The location of the passage vortex at the far downstream exit plane is dependent upon rotor position, as reported in earlier studies. A complete data set of the mean and fluctuating velocity components at all sixteen time windows is available on diskette. Author

A93-19395* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THREE-DIMENSIONAL FLOW PHENOMENA IN A TRANSONIC, HIGH-THROUGH-FLOW, AXIAL-FLOW COMPRESSOR STAGE
WILLIAM W. COPENHAVER (USAF, Wright Lab., Wright-Patterson AFB, OH), CHUNILL HAH (NASA, Lewis Research Center, Cleveland, OH), and STEVEN L. PUTERBAUGH (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by USAF refs
(ASME PAPER 92-GT-169)

A detailed aerodynamic study of a transonic, high-through-flow, single stage compressor is presented. The compressor stage was comprised of a low-aspect-ratio rotor combined alternately with two different stator designs. Both experimental and numerical studies are conducted to understand the details of the complex flow field present in this stage. Aerodynamic measurements using high-frequency, Kulite pressure transducers and conventional probes are compared with results from a three-dimensional viscous flow analysis. A steady multiple blade row approach is used in the numerical technique to examine the detailed flow structure inside the rotor and the stator passages. The comparisons indicate that many flow field features are correctly captured by viscous flow analysis, and therefore unmeasured phenomena can be studied with some level of confidence. Author

A93-19399* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NUMERICAL SOLUTIONS FOR UNSTEADY SUBSONIC VORTICAL FLOWS AROUND LOADED CASCADES
J. FANG and H. M. ATASSI (Notre Dame Univ., IN) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract NAG3-732)
(ASME PAPER 92-GT-173)

A frequency domain linearized unsteady aerodynamic analysis is presented for three-dimensional unsteady vortical flows around a cascade of loaded airfoils. The analysis fully accounts for the distortion of the impinging vortical disturbances by the mean flow. The entire unsteady flow field is calculated in response to upstream three-dimensional harmonic disturbances. Numerical results are presented for two standard cascade configurations representing turbine and compressor bladings for a reduced frequency range

from 0.1 to 5. Results show that the upstream gust conditions and blade sweep strongly affect the unsteady blade response.
Author

A93-19400* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FORCING FUNCTION EFFECTS ON UNSTEADY AERODYNAMIC GUST RESPONSE. I - FORCING FUNCTIONS
GREGORY H. HENDERSON and SANFORD FLEETER (Purdue Univ., West Lafayette, IN) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research sponsored by NASA refs
(ASME PAPER 92-GT-174)
The paper investigates the fundamental gust modeling assumption on the basis of a series of experiments performed in the Purdue Annular Cascade Research Facility. The measured unsteady flow fields are compared to linear-theory gust requirements. The perforated-plate forcing functions closely resemble linear-theory forcing functions, with the static pressure fluctuations small and the periodic velocity vectors parallel to the downstream mean-relative flow angle over the entire periodic cycle. The airfoil forcing functions exhibit characteristics far from linear-theory gusts, with the alignment of the velocity vectors and the static pressure fluctuation amplitudes dependent on the rotor-loading condition, rotor solidity, and the inlet mean-relative flow angle. It is shown that airfoil wakes, both compressor and turbine, cannot be modeled with the boundary conditions of current state-of-the-art linear unsteady aerodynamic theory. P.D.

A93-19401* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FORCING FUNCTION EFFECTS ON UNSTEADY AERODYNAMIC GUST RESPONSE. II - LOW SOLIDITY AIRFOIL ROW RESPONSE
GREGORY H. HENDERSON and SANFORD FLEETER (Purdue Univ., West Lafayette, IN) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research sponsored by NASA refs
(ASME PAPER 92-GT-175)
The paper investigates the fundamental gust modeling assumption on the basis of a series of experiments performed in the Purdue Annular Cascade Research Facility. The unsteady period flow field is generated by rotating flows of perforated plates and airfoil cascades, with the resulting unsteady periodic chordwise pressure response of a downstream low solidity stator row determined by miniature pressure transducers embedded within selected airfoils. When the forcing function exhibited the characteristics of a linear-theory gust, the resulting response on the downstream stator airfoils was in excellent agreement with the linear-theory models. When the forcing function did not exhibit linear-theory gust characteristics, the resulting unsteady aerodynamic response of the downstream stators was much more complex and correlated poorly with the linear-theory gust predictions. It is shown that the forcing function generator significantly affects the resulting gust response, with the complexity of the response characteristics increasing from the perforated-plate to the airfoil-cascade forcing functions. P.D.

A93-19409
INCIDENCE ANGLE AND PITCH-CHORD EFFECTS ON SECONDARY FLOWS DOWNSTREAM OF A TURBINE CASCADE
A. PERDICHIZZI (Brescia Univ., Italy) and V. DOSSENA (Milano, Politecnico, Milan, Italy) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-184)
This paper describes the results of an experimental investigation of the three-dimensional flow downstream of a linear turbine cascade at off-design conditions. The tests have been carried out for five incidence angles from -60 to + 35 degrees, and for three pitch-chord ratios: s/c = 0.58, 0.73, 0.87. Data include blade pressure distributions, oil flow visualizations, and pressure probe measurements. The secondary flow field has been obtained by traversing a miniature five hole probe in a plane located at 50 percent of an axial chord downstream of the trailing edge. The distributions of local energy loss coefficients, together with vorticity and secondary velocity plots show in detail how much the secondary flow field is modified both by incidence and cascade solidity variations. The level of secondary vorticity and the intensity of the crossflow at the endwall have been found to be strictly related to the blade loading occurring in the blade entrance region. Heavy changes occur in the spanwise distributions of the pitch averaged loss and of the deviation angle, when incidence or pitch-chord ratio is varied. Author

A93-19429* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HYPERSONIC FLOW SEPARATION IN SHOCK WAVE BOUNDARY LAYER INTERACTIONS
A. HAMED (Cincinnati Univ., OH) and AJAY KUMAR (NASA, Langley Research Center, Hampton, VA) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Previously announced in STAR as N90-15885 refs
(Contract NAS1-18458)
(ASME PAPER 92-GT-205)
An assessment is presented for the experimental data on separated flow in shock wave turbulent boundary layer interactions at hypersonic and supersonic speeds. The data base consists mainly of two dimensional and axisymmetric interactions in compression corners or cylinder-flares, and externally generated oblique shock interactions with boundary layers over flat plates or cylindrical surfaces. The conditions leading to flow separation and the subsequent changes in the flow empirical correlations for incipient separation are reviewed. The effects of the Mach number, Reynolds number, surface cooling and the methods of detecting separation are discussed. The pertinent experimental data for the separated flow characteristics in separated turbulent boundary layer shock interaction are also presented and discussed. Author

A93-19430
NUMERICAL SIMULATION OF THE FLOW FIELD AROUND SUPERSONIC AIR-INTAKES
G. FRESKOS (CERFACS, Toulouse, France) and O. PENANHOAT (SNECMA, Moissy-Cramayel, France) Jun. 1992 13 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-206)
Various studies in computational fluid dynamics related to supersonic inlets are presented. Two approaches are considered: the requirement for a code capable of calculating in a cost-efficient way the entire flow field around a 2D or 3D inlet to perform parametric studies, and the requirement for a code that can capture local phenomena to better understand inlet behavior. A sophisticated numerical scheme for the convective terms together with an implicit technique in the Navier-Stokes code are presented and validated by 2D calculations. R.E.P.

A93-19432
A FULLY THREE-DIMENSIONAL INVERSE METHOD FOR TURBOMACHINERY BLADING IN TRANSONIC FLOWS
T. Q. DANG (Syracuse Univ., NY) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Hawthorne Associates refs
(ASME PAPER 92-GT-209)
This paper presents a procedure to extend a recently developed fully three-dimensional inverse method for highly-loaded turbomachine blades into the transonic-flow regime. In this inverse method, the required three-dimensional blade profile to produce a prescribed swirl schedule is determined iteratively using the blade boundary conditions. In the present implementation, the flow is assumed to be inviscid and the blades are assumed to be infinitely

thin. The relevant equations are solved in the conservative forms and are discretized in all three directions using a finite-volume technique. Calculations are carried out for the design of high-pressure axial- and centrifugal-compressor rotors. These examples include prescribed swirl schedules that correspond to blade design that are shock-free and blade design that have rapid compression regions in the blade passage. Author

A93-19433

CALCULATION OF THREE-DIMENSIONAL BOUNDARY LAYERS ON ROTOR BLADES USING INTEGRAL METHODS

M. T. KARIMIPANAH and E. OLSSON (Chalmers Univ. of Technology, Goteborg, Sweden) Jun. 1992 14 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs

(ASME PAPER 92-GT-210)

The computer codes for calculating the compressible 3D turbulent and laminar boundary layers with rotation are tested by utilizing two different blades. Calculations for the stationary example where measured values are available, demonstrate good agreement with measurements. The calculations regarding rotation and compressibility show that these phenomena have strong effects on the boundary layer parameters and transition. R.E.P.

A93-19434

MEASUREMENT OF THE THREE-DIMENSIONAL TIP REGION FLOWFIELD IN AN AXIAL COMPRESSOR

R. C. STAUTER (United Technologies Research Center, East Hartford, CT) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by United Technologies Corp refs

(ASME PAPER 92-GT-211)

A two-color, five-beam LDV system has been configured to make simultaneous three-component velocity measurements of the flow field in a two-stage axial compressor model. The system has been used to make time-resolved measurements both between compressor blade rows as well as within the rotating blade passages in an axial compressor. The data show the nature and behavior of the complex, three-dimensional flow phenomena present in the tip region of a compressor as they convect downstream. In particular, the nature of the tip leakage vortex is apparent, being manifested by high blockage as well as the expected vortical motion. The data indicate that the radial flows associated with the tip leakage vortex begin to decrease while within the rotor passage, and that they temporarily increase aft of the passage. Author

A93-19436* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION OF THE NASA LOW-SPEED CENTRIFUGAL COMPRESSOR FLOW FIELD

M. D. HATHAWAY (U.S. Army, Combat and Material Research Labs., Cleveland, OH), R. M. CHRISS, J. R. WOOD, and A. J. STRAZISAR (NASA, Lewis Research Center, Cleveland, OH) Jun. 1992 17 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs

(ASME PAPER 92-GT-213)

An experimental and computational investigation of the NASA Low-Speed Centrifugal Compressor (LSCC) flow field has been conducted using laser anemometry and Dawes' 3D viscous code. The experimental configuration consists of a backswept impeller followed by a vaneless diffuser. Measurements of the three-dimensional velocity field were acquired at several measurement planes through the compressor. The measurements describe both the throughflow and secondary velocity field along each measurement plane. In several cases the measurements provide details of the flow within the blade boundary layers. Insight into the complex flow physics within centrifugal compressors is provided by the computational analysis, and assessment of the CFD predictions is provided by comparison with the measurements. Five-hole probe and hot-wire surveys at the inlet and exit to the rotor as well as surface flow visualization along the impeller blade surfaces provide independent confirmation of the laser measurement technique. Author

A93-19437

THE MEASUREMENT AND PREDICTION OF THE TIP CLEARANCE FLOW IN LINEAR TURBINE CASCADES

F. J. G. HEYES and H. P. HODSON (Cambridge Univ., United Kingdom) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Ministry of Defence Procurement Executive and Rolls-Royce, PLC refs

(ASME PAPER 92-GT-214)

This paper describes a simple two-dimensional model for the calculation of the leakage flow over the blade tips of axial turbines. The results obtained from calculations are compared with data obtained from experimental studies of two linear turbine cascades. One of these cascades has been investigated by the authors and previously unpublished experimental data is provided for comparison with the model. In each of the test cases examined, excellent agreement is obtained between the experimental and predicted data. Although ignored in the past, the importance of pressure gradients along the blade chord is highlighted as a major factor influencing the tip leakage flow. Author

A93-19439

ON THE CONSERVATION OF ROTHALPY IN TURBOMACHINES

F. A. LYMAN (Syracuse Univ., NY) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs

(ASME PAPER 92-GT-217)

The conditions under which rothalpy is conserved are investigated by means of the energy and moment-of-momentum equations for unsteady flow of a viscous, compressible fluid. Differential and integral equations are given for the total enthalpy and rothalpy in both stationary and rotating coordinates. From the equations in rotating coordinates it is shown that rothalpy may change due to: (1) pressure fluctuations caused by flow unsteadiness in the rotating frame; (2) angular acceleration of the rotor; (3) work done by viscous stresses on the relative flow in the rotating frame; (4) work done by body forces on the relative flow; and (5) changes in entropy due to viscous dissipation and heat transfer. Conclusions of this investigation are compared with those of previous authors, some of whom have stated that rothalpy is conserved even in viscous flows. A modified Euler's turbomachine equation which includes viscous effects is derived and errors in previous derivations noted. Author

A93-19445

ADVANCED DUCTED ENGINES - IMPACT OF UNSTEADY AERODYNAMICS ON FAN VIBRATION PROPERTIES

ARNO H. KLOSE (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Germany) Jun. 1992 4 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs

(ASME PAPER 92-GT-228)

Fans of Advanced Ducted Engines (ADE) will be built from light-weight materials such as carbon-fiber-reinforced plastics (CFRP). Due to their low density, the aeroelastic behavior of these fan blades is significantly different from that of conventional titanium fan blading. Calculations performed during the design of ADE fan bladings show that self-induced aerodynamic loads can significantly alter the resonant frequencies; furthermore, aerodynamic coupling of the different in-vacuo eigenmodes can occur. This is not the case for conventional titanium fan blading, where the vibration properties are largely unaffected by unsteady aerodynamic forces. It is concluded that for light-weight fan blading, it is necessary to take into account aerodynamic stiffening and aerodynamic mode coupling when computing eigenfrequencies and aeroelastic stability. Author

A93-19452
HEAT TRANSFER AND AERODYNAMICS OF A HIGH RIM SPEED TURBINE NOZZLE GUIDE VANE WITH PROFILED END WALLS
K. S. CHANA (Royal Aerospace Establishment, Propulsion Dept., Farnborough, United Kingdom) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-243)

It has been shown that the secondary flows present within turbine nozzle guide vanes have a marked effect on heat transfer. The horse-shoe and passage vortices, for example, have a major impact on platform and vane suction surface heat transfer. To investigate these effects further, heat transfer and aerodynamic measurements have been made on an annular transonic turbine nozzle guide vane ring, with three different platform geometries. The measurements were taken in the isentropic Light Piston test facility at RAE Pyestock at representative values of engine Reynolds number, Mach number and freestream gas-to-wall temperature ratio. This paper compares and discusses the measured platform and vane suction surface Nusselt and Mach number distributions for the three different endwall profiles. Comparisons with theoretical flow and heat transfer predictions are presented. Author

A93-19460
BALANCE OF MOMENTS FOR HYPERSONIC VEHICLES
FRANS G. J. KREMER (DLR, Inst. fuer Antriebstechnik, Cologne, Germany) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-251)

Ramjet engines propelling hypersonic flight vehicles will be highly integrated into the vehicle, resulting in strong interactions between the vehicle and the engine. An assessment of these interactions in relation to the flight mission is made by simple but adequate modeling of the flight vehicle aerodynamics and the engine performance. Especially moments associated with the propulsion system are of interest. This paper deals with the pitch moments introduced by the ramjet related forces, which are evaluated by one-dimensional engine performance and by modeling of the inlet and nozzle flow. Furthermore, it discusses the balance of moments for the first stage of a two stage transportation system for an ascent trajectory. Author

A93-19468
ON AERODYNAMIC LOADING OF LINEAR COMPRESSOR CASCADES
JAN CITAVY (PCS Spol. S. R. O., Prague, Czechoslovakia) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-275)

A study concerning a high loading of the pressure surface of a blade in a linear compressor cascade is presented. Assuming the 2D incompressible flow, two cascades have been designed using an inverse method and tested at the design and at the off-design incidence angles in a low-speed wind tunnel. The results are utilized for definition of the maximum permissible aerodynamic loading on both suction and pressure surfaces. R.E.P.

A93-19469
NUMERICAL RESEARCH ON FLOWS IN NONUNIFORM CASCADES
QI FENG, GUOCAI TANG, and CHUNHUA SHENG (Nanjing Aeronautical Inst., China) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-276)

In this paper, a fast and accurate multi-grid Euler flow solver was used to simulate flows in an uniform cascade under distorted outlet pressure, flows in nonuniform cascades under uniform boundary conditions, and flows in a nonuniform cascade under nonuniform outlet pressure. Results, including the variation of blade load in the uniform cascade under distorted outlet pressure, the propagation of outlet pressure distortion through the cascade, the flow mechanisms in nonuniform cascades, etc., were obtained. Finally a specific nonuniform cascade was designed, where the inlet pressure nonuniformity induced by outlet pressure distortion was greatly weakened through the cascade, which proves it is possible to reduce the propagation of outlet pressure distortion by a specially designed nonuniform cascade. Author

A93-19470
PREDICTION OF 2D VISCOUS TRANSONIC FLOW IN COMPRESSOR CASCADES USING A SEMI-EMPIRICAL SHOCK/BOUNDARY-LAYER INTERACTION METHOD
M. HOEGER and K. D. BROICHHAUSEN (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Germany) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-277)

A fast and robust calculation method for turbulent shock boundary-layer interaction is presented which enables the design engineer in quickly estimating the boundary-layer behavior of a transonic compressor profile section. The separated flow in the vicinity of a shock is described in terms of the boundary-layer properties ahead of the shock and the shock strength itself. The method is incorporated in an integral boundary-layer procedure and coupled with the Euler-equations by the equivalent source concept. Calculations for the flow in transonic and supersonic compressor cascades demonstrate the ability of the present method and show good agreement with boundary-layer properties and Mach number distributions obtained from measurements. Author

A93-19473
TRANSITION PREDICTION IN ATTACHED AND SEPARATED SHEAR LAYERS USING AN INTEGRAL METHOD
G. LEOUTSAKOS and K. D. PAPAILIOU (Athens National Technical Univ., Greece) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by EEC refs
(ASME PAPER 92-GT-281)

A low cost and rapid engineering prediction technique is developed for the computation of transitional shear layers like the ones encountered on turbomachinery blading. Both attached flows and separated flows can be treated equally well. Compressibility is included in the formulation of the technique, although validation is limited to incompressible attached and separated cases, on flat plate and airfoil geometries. R.E.P.

A93-19474
AN APPROACH FOR MULTI-STAGE CALCULATIONS INCORPORATING UNSTEADINESS
MICHAEL GILES (MIT, Cambridge, MA) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-282)

This paper describes a mathematical approach to the calculation of unsteady flow in multi-stage turbomachinery. An asymptotic formulation is used, with the small asymptotic parameter being the level of unsteadiness in each blade row. The baseline flow is the nonlinear steady flow that is computed by many existing multi-stage calculation methods. The first order linear perturbation is the unsteady flow field arising from stator/rotor interactions between neighboring blade rows. The second order correction contains the information about the time-averaged effect of unsteadiness on the mean flow. The advantage of this asymptotic approach is that it leads to a set of equations which can be solved numerically very much cheaply than the full nonlinear unsteady flow equations, while still retaining the key features of the flow. Author

A93-19475
UNSTEADY BOUNDARY-LAYER TRANSITION IN FLOW PERIODICALLY DISTURBED BY WAKES
U. ORTH (Darmstadt, Technische Hochschule, Germany) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by DFG refs
(ASME PAPER 92-GT-283)
Boundary layers on turbomachinery blades develop in a flow which is periodically disturbed by the wakes of upstream blade cascades. These wakes have a significant effect upon laminar-turbulent boundary-layer transition. In order to study these effects, detailed velocity measurements using hot-wire probes were performed within the boundary-layer of a plate in flow periodically disturbed by wakes produced by bars moving transversely to the flow. The measurements were evaluated using the ensemble-averaging technique. The results show how the wake disturbance enters the boundary-layer and leads to a turbulent patch, which grows and is carried downstream. In favorable pressure gradients, transition due to wake turbulence occurred much earlier than predicted by linear stability theory. Between two wakes, laminar becalmed regions were observed far beyond the point at which the undisturbed boundary-layer was already turbulent. Author

A93-19477
DESIGN OF MULTI-STAGE TURBOMACHINERY BLADING BY THE CIRCULATION METHOD - ACTUATOR DUCT LIMIT
T. Q. DANG and T. WANG (Syracuse Univ., NY) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research sponsored by New York State Energy and Research Development Authority refs
(ASME PAPER 92-GT-286)
This paper presents an extension of a recently developed three-dimensional inverse method for turbomachine blades to handle multistage machines in the limit of an infinite number of blades in each blade row. The axisymmetric flowfield is assumed to be inviscid, compressible, and rotational. The use of blockage and entropy-increase terms are included in the theory to model losses. An iterative procedure is presented for the calculations of the blade profiles which produce prescribed swirl schedules in the bladed regions. The numerical technique employed to solve the relevant equations is based on a finite-volume formulation. The method is applied to the design of a low-pressure multi-stage centrifugal compressor used in industrial processing. Author

A93-19479
PREDICTION OF SECONDARY LOSSES IN AXIAL COMPRESSORS
VACLAV CYRUS (National Research Inst. for Machine Design, Prague, Czechoslovakia) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-288)
A large number of both published and own experimental data on secondary losses in straight compressor cascades and compressor blade rows has been reviewed. Published correlations for prediction of secondary losses have been compared to chosen experiments. Two cases of the blade and end-wall design have been investigated-blade with and without tip clearance. On the basis of experimental results, new improved correlations for secondary loss coefficient have been derived. These have been implemented in the program for characteristics computation of axial compressors and an improved agreement between predictions and experiments has been obtained. Author

A93-19482
A THREE-DIMENSIONAL NUMERICAL METHOD FOR TURBOMACHINERY BLADING
C. W. GU, J. Z. XU, and J. Y. DU (Chinese Academy of Sciences, Inst. of Engineering Thermophysics, Beijing, China) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-291)
By inversing one of the stream functions and their principal equations in a three-dimensional flow the equations with the second-order partial derivatives of both the coordinate and another stream function are derived. The corresponding boundary conditions are easily specified. Based on these equations and the boundary conditions the convergent solution for turbomachinery blading is obtained. The computational results show that the method is simple and effective. Author

A93-19483
A VISCOUS AXISYMMETRIC THROUGHFLOW PREDICTION METHOD FOR MULTI-STAGE COMPRESSORS
AHMET S. UCER (Middle East Technical Univ., Ankara, Turkey) and RAYMOND P. SHREEVE (U.S. Naval Postgraduate School, Monterey, CA) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-293)
This paper describes a computer code which solves viscous axisymmetric flow through multistage compressors. The code incorporates the modelling of 3-D effects which result from secondary flow and mixing and lead to property changes in the streamwise and spanwise directions. The method requires no extra data for loss, deviation and blockage. The necessary input data are the geometry, upstream stagnation conditions, rotationa1 speed and mass flow rate. Blade wakes and their decay are modelled. The secondary flow component of the mixing coefficient modifies the uniform part and the result is used in the turbulent diffusion terms of the equation of motion. The P&W 3S1 low aspect ratio 3 stage compressor and UTRC 2 stage research compressor are used for validation. Considering the complexity of the flow in the multi-stage environment, it was concluded that the method gives encouraging results at a very economical rate. Author

A93-19484
A SIMPLE METHOD FOR ESTIMATING SECONDARY LOSSES IN TURBINES AT THE PRELIMINARY DESIGN STAGE
M. B. OKAN and D. G. GREGORY-SMITH (Durham Univ., United Kingdom) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Ministry of Defence Procurement Executive and Rolls-Royce, PLC refs
(ASME PAPER 92-GT-294)
Reasonably accurate estimation of losses at an early design stage plays an important part in the success of a turbine design. Although various computational methods exist for estimating the profile loss, for secondary losses which are equally important, designers still rely on empirical estimates. A method has been developed for estimating the secondary flow and secondary losses within an axial turbine cascade. It is assumed that the inlet boundary layer is convected into a loss core within the blade passage while extra loss has been generated due to the secondary kinetic energy and a new boundary layer that is developing on the end wall. The method has been applied to various test cases and the results show that the basic approach is reliable. Author

A93-19488
A COMPARISON OF THE MEASURED AND PREDICTED FLOWFIELD IN A MODERN FAN-BYPASS CONFIGURATION
R. K. GOYAL (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) and W. N. DAWES (Cambridge Univ., United Kingdom) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-298)
A 3-D viscous Navier-Stokes flow solver was used to predict core and bypass rotor performance and radial flow characteristics of a 4.6:1 bypass ratio, single stage fan. The 3-D flow solver can handle several blade rows simultaneously and has the capability to include a downstream splitter. Results of the analysis are

compared with experimental data obtained during rig testing of a modern high bypass single stage turbofan in which rotor performance for both bypass and core streams was measured. Author

A93-19489
INVESTIGATION OF TIP CLEARANCE PHENOMENA IN AN AXIAL COMPRESSOR CASCADE USING EULER AND NAVIER-STOKES PROCEDURES
R. F. KUNZ, B. LAKSHMINARAYANA, and A. H. BASSON (Pennsylvania State Univ., University Park) Jun. 1992 23 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract DAAL03-86-G-0044)
(ASME PAPER 92-GT-299)

Three-dimensional Euler and Full Navier-Stokes computational procedures have been utilized to simulate the flow field in an axial compressor cascade with tip clearance. An embedded H-grid topology was utilized to resolve the flow physics in the tip gap region. The numerical procedure employed is a finite difference Runge-Kutta scheme. Available measurements of blade static pressure distributions along the blade span, dynamic pressure and flow angle in the cascade outlet region, and spanwise distributions of blade normal force coefficient and circumferentially averaged flow angle are used for comparison. Several parameters which were varied in the experimental investigations were also varied in the computational studies. Specifically, measurements were taken and computations were performed on the configuration with and without: tip clearance, the presence of an endwall, inlet endwall total pressure profiles and simulated relative casing rotation. Additionally, both Euler and Navier-Stokes computations were performed to investigate the relative performance of these approaches in reconciling the physical phenomena considered. Results indicate that the Navier-Stokes procedure, which utilizes a low Reynolds number k-epsilon model, captures a variety of important physical phenomena associated with tip clearance flows with good accuracy. These include tip vortex strength and trajectory, blade loading near the tip, the interaction of the tip clearance flow with passage secondary flow and the effects of relative endwall motion. The Euler computation provides good but somewhat diminished accuracy in resolution of some of these clearance phenomena. It is concluded that the level of modelling embodied in the present approach is sufficient to extract much of the tip region flow field information useful to designers of turbomachinery. Author

A93-19490* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NUMERICAL SIMULATION OF COMPRESSOR ENDWALL AND CASING TREATMENT FLOW PHENOMENA
A. J. CROOK (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), E. M. GREITZER, C. S. TAN (MIT, Cambridge, MA), and J. J. ADAMCZYK (NASA, Lewis Research Center, Cleveland, OH) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by General Motors Corp refs
(ASME PAPER 92-GT-300)

A numerical study is presented of the flow in the endwall region of a compressor blade row, in conditions of operation with both smooth and grooved endwalls. The computations are first compared to velocity field measurements in a cantilevered stator/rotating hub configuration to confirm that the salient features are captured. Computations are then interrogated to examine the tip leakage flow structure since this is a dominant feature of the endwall region. In particular, the high blockage that can exist near the endwalls at the rear of a compressor blade passage appears to be directly linked to low total pressure fluid associated with the leakage flow. The fluid dynamic action of the grooved endwall, representative of the casing treatments that have been most successful in suppressing stall, is then simulated computationally and two principal effects are identified. One is suction of the low total pressure, high blockage fluid at the rear of the passage. The second is energizing of the tip leakage flow, most notably in the core of the leakage vortex, thereby suppressing the blockage at its source. Author

A93-19491
THE ROLE OF LAMINAR-TURBULENT TRANSITION IN GAS TURBINE ENGINES - A DISCUSSION
G. J. WALKER (Tasmania Univ., Hobart, Australia) Jun. 1992 13 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Australian Research Council and Rolls-Royce, PLC refs
(ASME PAPER 92-GT-301)

An extended discussion of Mayle's (1991) critical study of transition phenomena in gas turbine engines is presented. Attention is focussed on transition in decelerating flow regions which are the major sources of loss production for axial turbomachine blades. The following points are examined in detail: (a) the physics of transition and its implications for the correlation of various transition phenomena; (b) the relative importance of pressure gradient and freestream turbulence in controlling transition; (c) the influence of pressure gradient on periodic-unsteady transition; (d) the correlation of transition length under conditions of arbitrary pressure gradient and free-stream turbulence level; and (e) transition behavior in laminar separation bubbles. The discussion examines various differences in philosophy concerning the above phenomena and corrects some areas of misinterpretation in the subject review paper. It concludes with further suggestions for transition research which may assist in resolving the issues raised. Author

A93-19492
VISCOUS THROUGHFLOW MODELLING FOR MULTI-STAGE COMPRESSOR DESIGN
M. A. HOWARD and S. J. GALLIMORE (Rolls-Royce, PLC, Derby, United Kingdom) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-302)

An existing throughflow method for axial compressors, which accounts for the effects of spanwise mixing using a turbulent diffusion model, has been extended to include the viscous shear force on the endwall. The use of a shear force, consistent with a no-slip condition, on the annulus walls in the throughflow calculations allows realistic predictions of the velocity and flow angle profiles near the endwalls. The annulus wall boundary layers are therefore incorporated directly in the throughflow prediction. This eliminates the need for empirical blockage factors or independent annulus boundary layer calculations. The axisymmetric prediction can be further refined by specifying realistic spanwise variations of loss coefficient and deviation to model the three-dimensional endwall effects. The resulting throughflow calculation gives realistic predictions of flow properties across the whole span of a compressor. This is confirmed by comparison with measured data from both low and high speed multi-stage machines. The viscous throughflow method has been incorporated into an axial compressor design system. The method predicts the meridional velocity defects in the endwall region and consequently blading can be designed which allows for the increased incidence, and low dynamic head, near to the annulus walls. Author

A93-19496
CALCULATION OF WAKE-INDUCED UNSTEADY FLOW IN A TURBINE CASCADE
N.-H. CHO, X. LIU, W. RODI, and B. SCHOENUNG (Karlsruhe Univ., Germany) Jun. 1992 13 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research sponsored by Forschungsvereinigung Verbrennungskraftmaschinen refs
(Contract BMFT-0326801G)
(ASME PAPER 92-GT-306)

Numerical predictions are reported of two-dimensional unsteady flow in a linear turbine cascade, where the unsteadiness is caused by passing wakes generated by the preceding row of blades. In

particular, an experiment is simulated in which the passing wakes were generated by cylinders moving on a rotating squirrel cage. Blade-to-blade calculations were carried out by solving the unsteady 2D flow equations with an accurate finite-volume procedure, thereby resolving the periodic unsteady motion. The effects of stochastic turbulent fluctuations are simulated with a two-layer turbulence model, in which the standard k-epsilon model is applied in the bulk of the flow and a one-equation model in the near-wall region. This involves also a transition model based on an empirical formula due to Abu-Ghannam and Shaw (1980), which was adapted for the unsteady situation by applying it in a Lagrangean way, following fluid parcels in the boundary layer underneath disturbed and undisturbed free stream on their travel downstream. The calculations are compared with experiments for various wake-passing frequencies. On the whole, the complex unsteady flow behaviour is simulated realistically, including the moving forward of transition when the wake-passing frequency increases, but not all details can be reproduced. Author

A93-19498
AN INVESTIGATION OF TURBULENCE MODELLING IN TRANSONIC FANS INCLUDING A NOVEL IMPLEMENTATION OF AN IMPLICIT K-EPSILON TURBULENCE MODEL
MARK G. TURNER and IAN K. JENNIONS (GE Aircraft Engines, Cincinnati, OH) Jun. 1992 14 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-308)

An explicit Navier-Stokes solver has been written with the option of using one of two types of turbulence models. One is the Baldwin-Lomax algebraic model and the other is an implicit k-epsilon model which has been coupled with the explicit Navier-Stokes solver in a novel way. This type of coupling, which uses two different solution methods, is unique and combines the overall robustness of the implicit k-epsilon solver with the simplicity of the explicit solver. The resulting code has been applied to the solution of the flow in a transonic fan rotor which has been experimentally investigated by Wennerstrom. Five separate solutions, each identical except for the turbulence modelling details, have been obtained and compared with the experimental results. The five different turbulence models run were: the standard Baldwin-Lomax model both with and without wall functions, the Baldwin-Lomax model with modified constants and wall functions, a standard k-epsilon model and an extended k-epsilon model which accounts for multiple time scales by adding an extra term to the dissipation equation. In general, as the model includes more of the physics, the computed shock position becomes closer to the experimental results. Author

A93-19499
THREE-DIMENSIONAL NAVIER-STOKES COMPUTATIONS OF TRANSONIC FAN FLOW USING AN EXPLICIT FLOW SOLVER AND AN IMPLICIT K-EPSILON SOLVER
I. K. JENNIONS and MARK G. TURNER (GE Aircraft Engines, Cincinnati, OH) Jun. 1992 14 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-309)

Computational fluid dynamics (CFD) has become a powerful ally of the experimental test facility in revealing the flow physics of some highly complex flows. For certain classes of flow, CFD has reached maturity and is therefore being increasingly used in industry by designers. This paper is intended to show current transonic prediction capability at GE Aircraft Engines in terms of a recently developed 3D Navier-Stokes code. The flow simulations addressed are concerned with transonic fan design and illustrate those issues that are important to designers such as tip leakage flow, shock boundary layer interaction, boundary layer growth and account of internal solid bodies such as part-span shrouds and engine splitters. In this respect, three successively more complex Navier-Stokes simulations representative of modern fans: NASA Rotor 67, GE/Wennerstrom Rotor 4, and the GE/NASA E3 fan, are considered in this paper. Author

A93-19507
MEASUREMENT OF UNSTEADY FLOW AND HEAT TRANSFER IN A LINEAR TURBINE CASCADE
X. LIU (Pratt & Whitney Canada, Mississauga) and W. RODI (Karlsruhe Univ., Germany) Jun. 1992 15 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract BMFT-0326501-D)
(ASME PAPER 92-GT-323)

A detailed experimental study has been conducted on the wake-induced unsteady flow and heat transfer in a linear turbine cascade. The unsteady wakes with passing frequencies in the range zero to 240 Hz were generated by moving cylinders on a squirrel cage device. The velocity fields in the blade-to-blade flow and in the boundary layers were measured with hot-wire anemometers, the surface pressures with a pressure transducer and the heat transfer coefficients with a glue-on hot film. The results were obtained in ensemble-averaged form so that periodic unsteady processes can be studied. Of particular interest was the transition of the boundary layer. The boundary layer remained laminar on the pressure side in all cases and in the case without wakes also on the suction side. On the latter, the wakes generated by the moving cylinders caused transition, and the beginning of transition moves forward as the cylinder-passing frequency increases. Unlike in the flat-plate study of Liu and Rodi (1991 a) the instantaneous boundary layer state does not respond to the passing wakes and therefore does not vary with time. The heat transfer increases under increasing cylinder-passing frequency even in the regions with laminar boundary layers due to the increased background turbulence. Author

A93-19508
USE OF ADVANCED CFD CODES IN THE TURBOMACHINERY DESIGN PROCESS
O. NOVAK, O. SCHAEFER, B. SCHOENUNG (ABB Turbo Systems, Ltd., R&D Thermal Machinery Dept., Baden, Switzerland), and H. PAETZOLD (Interkeller, Ltd., Bruttisellen, Switzerland) Jun. 1992 13 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-324)

This paper describes the development and application of CFD codes, based on time-marching finite-volume formulations to the flow analysis in blade cascades, blade rows and stages of modern turbomachines. Special attention is paid to the reduction of the numerical dissipation of finite-volume discretization schemes, the numerical simulation of shock waves and to viscous effects. Furthermore, the application of solution-adaptive structured and unstructured computational grids is investigated. Finally, the ability of time-marching finite-volume methods to simulate three-dimensional flow effects in turbomachinery bladings is demonstrated. Author

A93-19509
MERIDIONAL FLOW CALCULATION USING ADVANCED CFD TECHNIQUES
P. KIOUSIS, P. CHAVIAROPOULOS, and K. D. PAPAILIOU (Athens National Technical Univ., Greece) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-325)

A computational tool suitable for solving the meridional through flow equations for turbomachinery applications is presented. Under the assumption that the flow is compressible and inviscid, the governing equations are obtained using a streamfunction formulation for the pitch-averaged flow equations. Viscous corrections are incorporated in the inviscid model in terms of flow angle deviation and total pressure losses. Body-fitted finite difference schemes are used to discretize governing equations. An artificial density upwinding scheme assures convergence in the transonic region. Particular attention is paid to the numerical integration procedure which is based on a preconditioned gradient method. Calculation results for low- and high-speed turbomachines

are presented and discussed. It is shown that the proposed numerical treatment performs satisfactorily both in accuracy and rapidity of the convergence. C.A.B.

A93-19510
EFFECT OF MANUFACTURING DEVIATIONS ON PERFORMANCE OF AXIAL FLOW COMPRESSOR BLADING
EZIO MARSON (Westinghouse Canada, Inc., Power Generation Technology Div., Hamilton) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-326)

Successful compressor aerodynamic performance can be achieved by satisfactory completion of requirements in the following three areas: aerodynamic design, quality of blading, and manufacturing and assembly of the components. Using presently available computer programs capable of doing detailed 3D analysis of the flow field, it is possible to obtain excellent aerodynamic designs exceeding 90 percent isentropic efficiency. When the design requirements are deviated from the manufacturing process, the result will be less than optimum performance. Different types of manufacturing deviations and their effect on compressor performance are analyzed in the paper by means of empirical formulas and considerations. Author

A93-19521
SEPARATED FLOW IN A LOW SPEED TWO-DIMENSIONAL CASCADE. I - FLOW VISUALIZATION AND TIME-MEAN VELOCITY MEASUREMENTS
ADAM M. YOCUM (Pennsylvania State Univ., State College) and WALTER F. O'BRIEN (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jun. 1992 13 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research sponsored by USAF refs
(ASME PAPER 92-GT-356)

This study was conducted for the purpose of providing a more fundamental understanding of separated flow in cascades and to provide performance data for fully-stalled blade rows. Cascades of a single blade geometry and a solidity of unity were studied for three stagger angles and the full range of angle of attack, extending well into the stalled flow regime. Results are presented from flow visualization and time-mean velocity measurements of stalled flow in the cascade. Surface and smoke flow visualization revealed that the blade stagger angle is a key parameter in determining the location of the separation line and the occurrence of propagating stall. Time-mean velocity measurements obtained with a dual hot split-film probe also showed that the separated velocity profiles within the blade passages and the profiles in the wake have distinctly different characteristics depending on the stagger angle. Author

A93-19522
SEPARATED FLOW IN A LOW SPEED TWO-DIMENSIONAL CASCADE. II - CASCADE PERFORMANCE
ADAM M. YOCUM (Pennsylvania State Univ., State College) and WALTER F. O'BRIEN (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jun. 1992 15 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research sponsored by USAF refs
(ASME PAPER 92-GT-357)

Results for blade pressure distributions and static and total pressure profiles measured in a 2D cascade under fully-stall conditions (separation from the blade leading edge) are presented. The static and total pressure profiles were measured using a pneumatic probe by aligning the probe with the flow at the angle determined with a dual split-film probe. R.E.P.

A93-19527
THE EXTENSION OF A SOLUTION-ADAPTIVE 3D NAVIER-STOKES SOLVER TOWARDS GEOMETRIES OF ARBITRARY COMPLEXITY
W. N. DAWES (Cambridge Univ., United Kingdom) Jun. 1992 14 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-363)

This paper describes recent developments to a three dimensional, unstructured mesh, solution-adaptive Navier-Stokes solver. By adopting a simple, pragmatic but systematic approach to mesh generation, the range of simulations which can be attempted is extended towards arbitrary geometries. The combined benefits of the approach result in a powerful analtyical ability. Solutions for a wide range of flows are presented including a transonic compressor rotor, a centrifugal impellor, a steam turbine nozzle guide vane with casing extraction belt, the internal coolant passage of a radial inflow turbine and a turbine disk-cavity flow. Author

A93-19528
RADIAL TRANSPORT AND MOMENTUM EXCHANGE IN AN AXIAL COMPRESSOR
ROBERT P. DRING (United Technologies Research Center, East Hartford, CT) Jun. 1992 14 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-364)

The objective of this work was to examine radial transport in axial compressors from two perspectives. The first was to compare the mixing coefficient based on a secondary flow model (using measured radial velocities) with that based on a turbulent diffusion model. The second was to use measured airfoil pressure forces and momentum changes to assess the validity of the assumption of diffusive radial transport which is common to both models. These examinations were carried out at both design and off-design conditions as well as for two rotor tip clearances. In general it was seen that radial mixing was strongest near the hub and that it increased dramatically at near-stall conditions. It was also seen that radial transport could cause large differences (about 100 percent) between the force on an airfoil and the change in momentum across the airfoil at the same spanwise location. Author

A93-19530
PRESCRIBED-CURVATURE-DISTRIBUTION AIRFOILS FOR THE PRELIMINARY GEOMETRIC DESIGN OF AXIAL-TURBOMACHINERY CASCADES
THEODOSIOS KORAKIANITIS (Washington Univ., Saint Louis, MO) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-366)

A technique for generating two-dimensional blade shapes is described. The geometry near the trailing edge is specified by an analytic polynomial, the principal portion of the blade surface is mapped employing as input a prescribed surface-curvature distribution, and the leading edge is specified as a thickness distribution added to a construction line. The technique may be utilized to generate subsonic or supersonic airfoils for turbines and compressors, or isolated airfoils. R.E.P.

A93-19543
ANALYSIS OF THREE-DIMENSIONAL VISCOUS FLOW IN A SUPERSONIC AXIAL FLOW COMPRESSOR ROTOR WITH EMPHASIS ON TIP LEAKAGE FLOW
G. PERRIN, F. LEBOEUF (Lyon, Ecole Centrale, Ecully, France), and W. N. DAWES (Cambridge Univ., United Kingdom) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Electricite de France, SEP, SNECMA, Turbomeca, Royal Society, and CNRS refs
(ASME PAPER 92-GT-388)

A three-dimensional computation has been performed for a supersonic axial flow compressor rotor by solving the Navier-Stokes equations. The results of the computation are used to analyze the tip leakage flow in more detail. As well as the global behavior of this vortex, the analysis focuses on the origins of this vortex. It

is shown that the main source of its vorticity is the shear layer at the tip of the blade associated with the shedding of the blade loading. A separation occurs, with respect to the axial velocity component, as the jet leakage flow, crossing the clearance gap, encounters the upstream incoming flow. Although the entropy increase of this separation is low, it has a strong effect on the mixing around the leakage vortex. Overall, for this compressor and the choosen operating point, the tip leakage effects are localized near the tip wall and suction side of the blade. Author

A93-19545
FLOW STUDIES IN DUCTED TWIN-ROTOR CONTRA-ROTATING AXIAL FLOW FANS
BHASKAR ROY, K. RAVIBABU, P. SRINIVASA RAO, S. BASU, A. RAJU, and P. N. MURTHY (Indian Inst. of Technology, Bombay, India) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Aeronautical Research and Development Board refs
(ASME PAPER 92-GT-390)

The design and testing of a 400 mm diam contrarotating fan unit was undertaken to study the flow behavior through the contrarotating fans, and to find ways and means of improving their design and performance. The performance characteristics of the two-fan unit have shown that large overall stall margins can be achieved. Also, the effect of axial gaps showed that at the design speed combination best performance was observed at an axial gap of 50 percent of the first fan chord. Studies on the second fan exit flow field identified performance characteristics of individual fans and casing boundary layer development. Significant performance enhancement is observed with serration on the second fan rotor blade surface. When casing boundary layer suction is employed in between the two blades, the second fan exit flow shows better uniformity and increased total pressure at all radii. Author

A93-19549
ACCURACY ISSUES IN THE PREDICTION OF SUPERSONIC INLET FLOWS
G. C. PAYNTER and E. TJONNELAND (Boeing Co., Seattle, WA) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-400)

Modeling and numerical accuracy issues are examined for two types of inlet flow analyses through a discussion of how modeling and numerical errors can influence the predicted inlet performance. Navier-Stokes and zonal analyses are presently being employed to support the design of supersonic inlets. The zonal analysis is utile for design screening of rectangular and axisymmetric inlets while Navier-Stokes analyses are utile for evaluating and fine-tuning the configurations chosen from the screening process. R.E.P.

A93-19566
ANALYSIS OF JET/WAKE MIXING IN A VANELESS DIFFUSER
JON S. MOUNTS (United Technologies Research Center, East Hartford, CT) and JOOST J. BRASZ (Carrier Corp., Syracuse, NY) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-418)

A 3D time-dependent Navier-Stokes algorithm is developed to study the unsteady flowfield interaction in the impeller and vaneless diffuser of a centrifugal compressor. This study describes the flow phenomena occurring in the entry region of a vaneless diffuser receiving the distorted impeller discharge flow. In the diffuser entry region, the initial dynamic variations in the velocity and flow angle mix out rapidly. R.E.P.

A93-19567
A NOVEL APPROACH TO HIGH RESOLUTION COMPRESSIBLE CASCADE FLOW ANALYSIS USING THE NAVIER-STOKES EQUATIONS
E. Y-K. NG and W. N. DAWES (Cambridge Univ., United Kingdom) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Singapore Chinese Chamber of Commerce and Industry and Cambridge Commonwealth Scholarship refs
(ASME PAPER 92-GT-419)

This paper deals with the development of a technique aimed at improving the accuracy of 2D flow solutions of turbomachinery problems. The basic concept is to take a quasi-3D Navier-Stokes or Euler solver on a coarse mesh (the 'outer code') and couple it to a 2D space marching parabolized Navier-Stokes solver on a finer sub-mesh (the 'inner code'). The 'inner-code' includes the FLARE approximation to permit reverse flow. The inner and outer codes are coupled by adopting an approach analogous to classical multigrid methods. The combination forms a cheap and fast solver to provide fine resolution solutions using only mini-computer resources. Predictions of the flow through a compressor and a turbine cascade are described and show good agreement with the experimental results. Author

A93-19570
UNSTEADY AERODYNAMICS AND GUST RESPONSE IN COMPRESSORS AND TURBINES
S. R. MANWARING and D. C. WISLER (GE Aircraft Engines, Cincinnati, OH) Jun. 1992 16 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-422)

A comprehensive series of analyses and experiments are conducted on turbine and compressor blading to evaluate the ability of current, practical, engineering/analysis models to predict unsteady aerodynamic loading of modern gas turbine blading. The tests were performed in low-speed research facilities capable of simulating the relevant aerodynamic features of turbomachinery. A detailed comparison of the analysis techniques is made and the importance of properly accounting for both vortical and potential disturbances is shown. R.E.P.

A93-19574
EXPERIMENTAL STUDY ON THE THREE DIMENSIONAL FLOW WITHIN A COMPRESSOR CASCADE WITH TIP CLEARANCE. I - VELOCITY AND PRESSURE FIELDS
SHUN KANG and CH. HIRSCH (Brussel, Vrije Univ., Brussels, Belgium) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-215)

Experimental results from a study of the 3D flow in a linear compressor cascade with stationary endwall at design conditions are presented for tip clearance levels of 1.0, 2.0 and 3.3 percent of chord, compared with the no clearance case. In addition to five-hole probe measurements, extensive surface flow visualizations are conducted. It is observed that for the smaller clearance cases a weak horseshoe vortex forms in the front of the blade leading edge. At all the tip gap cases, a multiple tip vortex structure with three discrete vortices around the midchord is found. The tip leakage vortex core is well defined after the midchord but does not cover a significantly great area in traverse planes. The presence of the tip leakage vortex results in the passage vortex moving close to the endwall and to the suction side. Author

A93-19575
EXPERIMENTAL STUDY ON THE THREE DIMENSIONAL FLOW WITHIN A COMPRESSOR CASCADE WITH TIP CLEARANCE. II - THE TIP LEAKAGE VORTEX
SHUN KANG and CH. HIRSCH (Brussel, Vrije Univ., Brussels, Belgium) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-432)

An analysis of the experimental data of a linear compressor cascade with tip clearance is presented with special attention to

the development of the tip leakage vortex. A method for determining the tip vortex core size, center position and vorticity or circulation from the measured data is proposed, based on the assumption of a circular tip vortex core. It is observed that the axial velocity profile passing through the tip vortex center is wake-like. The vorticity of the tip vortex increases rapidly near the leading edge and reaches its highest values at a short distance downstream, from which it gradually decreases. In the whole evolution, its size is growing and its center is moving away from both the suction surface and the endwall, approximately in a linear way. Author

A93-19966
SOME ASYMPTOTIC ASPECTS OF THE NONSTATIONARY AEROFOIL THEORY
Y. NAKAMURA (Kyushu Univ., Kasuga, Japan) Fluid Dynamics Research (ISSN 0169-5983) vol. 10, no. 3 Nov. 1992 p. 151-157. refs
Copyright

In a previous paper (Nakamura et al., 1992), it has been found that, in both attached and separated flow around an oscillating body, the effect of the wake undulation caused by the oscillation of the body can be vanishingly small in the asymptotic limit when the reduced frequency approaches infinity. Here, the asymptotic aspects of the nonstationary airfoil theory are reexamined in the light of this observation. In particular, attention is given to the Wagner function for impulsive start, the Theodorsen function for oscillatory motion, and the Kuessner function for an airfoil entering a sharp-edged gust. V.L.

A93-20116
INVESTIGATION OF THE CHARACTERISTICS OF 3-DIMENSIONAL SEPARATED FLOW IN AN ANNULAR COMPRESSOR BLADE ROW WITH LARGE ANGLES OF ATTACK
YUHONG LI, BIAO LU, and DAJUN YE (Tsinghua Univ., Beijing, China) Journal of Engineering Thermophysics (ISSN 0253-231X) vol. 13, no. 3 Aug. 1992 p. 254-260. In Chinese. refs

A detailed experimental investigation was carried out to examine the three-dimensional flow fields in an annular compressor cascade with large angles of attack at low Mach and Reynolds numbers. The flow fields at the inlet and outlet sections of the cascade were measured by a seven-hole probe. The inner flow field was visualized qualitatively by using the laser-sheet and particle technique. The flow patterns on the blade surfaces were shown by the oil-film method. Based on these results, we studied the characteristics and flow patterns of the 3D separated flow. These may be very helpful for improving the physical model of the complex flow with separation in a compressor cascade and for developing the 3D flow field diagnosis technique of turbomachinery. Author

A93-20117
A FOOL-PROOF AERODYNAMIC DESIGN CODE FOR TURBINE CASCADES
RUIXIAN CAI and YONGMEI HE (Chinese Academy of Sciences, Inst. of Engineering Thermophysics, Beijing, China) Journal of Engineering Thermophysics (ISSN 0253-231X) vol. 13, no. 3 Aug. 1992 p. 261-264. In Chinese. refs

An extremely simple, and universal turbine cascade design code is proposed and programmed. With its simplest operating condition, only four data are necessary to be input for obtaining the geometry of a good enough cascade. They are just the input data for designing a cascade: the inlet Mach number and flow angle, the outlet Mach number, and the specific heat ratio of the working substance. Therefore, the design can be accomplished without any additional human decision. The program is based on the mean-stream-line method. It is shown in detail how to select the independent design functions of this method in programming. This code can be run, even on a pocket computer, such as the Sharp PC-1500. Author

A93-20118
A CAD COMPUTER SYSTEM FOR CENTRIFUGAL COMPRESSOR IMPELLER WITH TRANSONIC INFLOW
XIAOLU ZHAO (Chinese Academy of Sciences, Inst. of Engineering Thermophysics, Beijing, China) and H. KRAIN (DLR, Inst. fuer Antriebstechnik, Cologne, Germany) Journal of Engineering Thermophysics (ISSN 0253-231X) vol. 13, no. 3 Aug. 1992 p. 269-272. In Chinese. refs

A computer-aided design system has been developed for high pressure ratio centrifugal compressor impellers with transonic inflow, based on the original one suitably only for subsonic inflow. The geometry is created by analytical functions. The quasi-3D calculation consists of S2 and S1 transonic flow solutions. Different boundary layer calculation methods are involved to take care of shock-boundary layer iterations. The comparisons between calculated and measured results taken within the impeller of a high pressure ratio centrifugal compressor are in fairly good agreement. Author

A93-20119
A UNIFIED MODEL FOR ROTATING STALL AND SURGE
DIYI TANG, JIE GUO, LIJUN LI, and WEIYANG QIAO (Northwestern Polytechnical Univ., Xian, China) Journal of Engineering Thermophysics (ISSN 0253-231X) vol. 13, no. 3 Aug. 1992 p. 273-276. In Chinese. refs

A new model describing the flow destabilizing mechanism in compressors is proposed on the basis of a detailed experimental study of instabilities in single-rotor, single-stage, and multistage compressors. Preliminary results of an investigation of the stability limit of axial flow compressor, including the rotating stall margin, are presented. The results indicate that, in the high-speed region, the stability limit is equivalent to a surge line; in the medium-speed region, the stability limit is in fact a stall line; and in the low-speed region, the stability limit has two branches, one of which is a stall line and the other is the rotating stall inception margin of the first stage. Mathematical methods for predicting the stability region are discussed. V.L.

A93-20120
THE COMPUTATION OF INTERNAL FLOW FIELDS IN CENTRIFUGAL COMPRESSOR IMPELLERS
XI CHEN and YONGMIAO MIAO (Xian Jiaotong Univ., China) Journal of Engineering Thermophysics (ISSN 0253-231X) vol. 13, no. 3 Aug. 1992 p. 277-281. In Chinese. refs

A method using k-epsilon turbulence model theory is proposed for solving the flow field in the centrifugal compressor impeller flow. In order to calculate the compressible flow, the variation of stage pressure and density are related through the friction loss and polytropic efficiency. The computing results of the internal flow field in two impellers are given. Author

A93-20144*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EFFECTS OF ICING ON THE AERODYNAMIC PERFORMANCE OF HIGH LIFT AIRFOILS
L. N. SANKAR, N. PHAENGSOOK, and A. BANGALORE (Georgia Inst. of Technology, Atlanta) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG3-768)
(AIAA PAPER 93-0026) Copyright

A 2D compressible Navier-Stokes solver capable of analyzing multi-element airfoils is described. The flow field is divided into multiple zones. In each zone, the governing equations are solved using an implicit finite difference scheme. The flow solver is validated through a study of the aerodynamic characteristics of a GA(W)-1 configuration, for which good quality measured surface pressure data and load data are available. The solver is next applied to a study of the effects of icing on an iced 5-element airfoil configuration, experimentally studied at NASA Lewis Research Center. It is demonstrated that the formation of ice over the leading edge slat and the main airfoil can lead to significant flow separation, and a significant loss in lift, compared to clean configurations. Author

A93-20146#
AERODYNAMIC DEGRADATION DUE TO DISTRIBUTED ROUGHNESS ON HIGH LIFT CONFIGURATION
J. N. BOER and J. VAN HENGST (Fokker Aircraft, Amsterdam, Netherlands) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0028) Copyright

The effect of distributed roughness on the lift characteristics of a two-dimensional wing section fitted with high lift devices was investigated in experiments conducted in the Low Speed Windtunnel of the Dutch National Aerospace Laboratory. It was found that roughness representative of contamination due to ground icing leads to a serious deterioration of the maximum lift and a considerable reduction of the angle of attack for maximum lift. Moreover, no critical roughness exists with zero losses. These conclusions apply for both the nonslatted and slatted configurations. I.S.

A93-20148#
A NEW SEMIEMPIRICAL METHOD FOR COMPUTING NONLINEAR ANGLE-OF-ATTACK AERODYNAMICS ON WING-BODY-TAIL CONFIGURATIONS
F. G. MOORE, L. DEVAN, and T. HYMER (U.S. Navy, Naval Surface Warfare Center, Dahlgren, VA) Jan. 1993 20 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by U.S. Navy refs
(AIAA PAPER 93-0034)

A new semiempirical method has been developed to predict normal force, pitching moment, and center of pressure on missile configurations up to angles of attack of 30 deg. The method is based on linear theory and slender body techniques at low angle of attack and uses wind tunnel data to derive nonlinear angle-of-attack corrections as angle of attack increases. The new improved theories include body alone, wing alone, and body-wing and wing-body interference. While the new theory is databased, simple analytical formulas are derived that allow general use of the techniques. Comparison with the linearized approaches used in the former NSWCDD aeroprediction code shows significant reductions in errors of aerodynamics above about 5 deg to 10 deg angle of attack. Limited comparisons to other state-of-the-art engineering codes show the new theory to be as good as or better than anything known to be available for computing planar aerodynamics up to 30 deg angle of attack. Author

A93-20152#
CONSTRAINED OPTIMIZATION OF THREE-DIMENSIONAL HYPERSONIC VEHICLE CONFIGURATIONS
SCOTT G. SHEFFER and GEORGE S. DULIKRAVICH (Pennsylvania State Univ., University Park) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0039) Copyright

A new method has been developed for preliminary design optimization of arbitrary (non-axisymmetric) hypersonic configurations in terms of aerodynamic wave drag. This optimization was accomplished while fixing certain parts of the geometry and maintaining the initial volume and length of the vehicle. Because of the large number of flow analysis evaluations required by this optimization algorithm, a fast and accurate analysis code based on modified Newtonian flow theory was used. This shape optimization method utilized an independent point-motion algorithm for each surface point. The spatial locations of the points defining each cross section were varied and a numerical optimization algorithm based on a quasi-Newton gradient search concept was used to determine the new optimal configuration. Two different configurations were optimized: a cone and a hypersonic plane configuration. Each of these configurations had certain individual cross sections or surface points fixed during the optimization process. Numerical results indicate a significant decrease in aerodynamic wave drag for simple and complex configurations at a low computing cost. Author

A93-20162*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A SENSITIVITY STUDY FOR PNEUMATIC VORTEX CONTROL ON A CHINED FOREBODY
R. E. BOALBEY, W. L. ELY, and B. A. ROBINSON (McDonnell Aircraft Co., Saint Louis, MO) Jan. 1993 17 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by NASA refs
(AIAA PAPER 93-0049) Copyright

A study was conducted to assess the sensitivity of yaw control on a chined forebody to the longitudinal location of a blowing slot at the chine edge. In addition, the effects of port blowing were also studied. NASA Langley's thin-layer Navier-Stokes code CFL3D was used to compare flow field characteristics and total yawing moment coefficients for the blowing configurations. Based upon equivalent blowing momentum coefficients, a significant increase in yaw control effectiveness was attained from the forward slot, relative to the aft slot, and port blowing was less effective than either slot blowing configuration. Author

A93-20163*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPERIMENTAL INVESTIGATION OF VORTEX-FIN INTERACTION
ANTHONY E. WASHBURN (Vigyan, Inc., Hampton, VA), LUTHER N. JENKINS (NASA, Langley Research Center, Hampton, VA), and MARTY A. FERMAN (McDonnell Douglas Corp., Saint Louis, MO) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS1-18585)
(AIAA PAPER 93-0050)

An experimental investigation has been conducted to examine the mechanisms of vortex-fin interaction on a twin-fin configuration. The investigation included a parametric study of the effect of tail location. The vortices were generated by a 76 deg sharp-edged delta wing with vertical tails mounted behind the wing. The model included both a dynamically-scaled flexible tail and a pressure instrumented rigid tail. Surface oil-flow patterns, off-body laser light sheet visualizations, aerodynamic load measurements, mean and unsteady flexible tail response, and unsteady tail surface pressure measurements were obtained. The results show that the tail location did not affect the upstream trajectory of the delta wing vortex. The tail location did affect the location of vortex breakdown, the global structure of the flow field, the aerodynamic loads, and the fin buffeting levels. The buffeting levels were reduced as the fins were moved laterally toward the vortex core trajectory. Two distinct peaks were observed in the pressure excitation spectra in the post-breakdown flow. Finally, the presence of the flexible tail opposite the rigid pressure tail altered the pressure measurements at one angle of attack. Author

A93-20164#
NUMERICAL ANALYSIS OF A CHINED FOREBODY WITH ASYMMETRIC STRAKES
KENNETH E. WURTZLER (USAF, Wright Lab., Wright-Patterson AFB, OH) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0051)

Forebody vortex flow control devices were numerically evaluated as to their control effectiveness on the Fighter Lift and Control (FLAC) model chined forebody. Strakes of various sizes were placed on the left front side of the FLAC forebody and low Mach number flow was simulated at high angles of attack. Results were computed by solving the steady-state Euler equations. Quantitative comparisons between each strake size were based on their ability to produce substantial yawing moments at high angles of attack. Qualitative comparisons of flow visualization were made from water tunnel results for verification of the computed vortex path. Incremental changes in the aerodynamic forces and moments on the forebody were calculated to understand the effectiveness of the various strake shapes. Results show that a short narrow strake placed at the apex of the forebody produces a strong vortex that remains near the centerline of the forebody,

creating a yawing moment to that side of the forebody. Wider strakes push the vortex away from the surface, causing a yawing moment to act in the opposite direction. Author

A93-20165#
STATIC ROLL MOMENT CHARACTERISTICS OF ASYMMETRIC TANGENTIAL LEADING EDGE BLOWING ON A DELTA WING AT HIGH ANGLES OF ATTACK
D. I. GREENWELL and N. J. WOOD (Bath Univ., United Kingdom) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0052) Copyright

The concept of asymmetric tangential leading edge blowing for the control of separated vortical flows is discussed. Test results for the development of roll moment on a delta wing at high angles of attack and sideslip are obtained and the underlying flow mechanisms examined. The application of the concept as an aircraft control system is addressed. R.E.P.

A93-20166#
THE AERODYNAMIC EFFECTS OF SIDESLIP ON DOUBLE DELTA WINGS
D. S. GRISMER, R. C. NELSON (Notre Dame Univ., IN), and W. L. ELY (McDonnell Aircraft Co., Saint Louis, MO) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by McDonnell Aircraft Co. and Univ. of Notre Dame refs
(AIAA PAPER 93-0053) Copyright

The results of an experimental examination into the effects of sideslip on the aerodynamic performance of a strake/wing planform is presented. The strake sweep, wing sweep and strake-to-wing fineness ratio for the model was 80 deg/60 deg/0.6. Flow visualization information was obtained by marking the strake and wing vortices with smoke in order to determine the state of the vortices (i.e., existence, pre- or post-breakdown state) and the three-dimensional coordinates of the vortex trajectories. Surface pressure measurements were taken on the strake and wing upper surfaces. Five-component force and moment data were also taken. The information obtained from each of these three different types of experiments was correlated to determine the effect of sideslip on the flow field and aerodynamic characteristics of the double delta wing. Author

A93-20167#
AN EXPERIMENTAL INVESTIGATION OF TWIN FIN BUFFETING AND SUPPRESSION
DAVID E. BEAN and NORMAN J. WOOD (Bath Univ., United Kingdom) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Defence Research Agency refs
(AIAA PAPER 93-0054) Copyright

An investigation is conducted to study the characteristics of vertical fin buffeting for various twin fin configurations at high angles of attack. To sense unsteady pressures at the fin surface, a rigid fin instrumented with miniature pressure transducers is fabricated, while a flexible fin of similar planform and size is utilized to measure the buffeting response. The buffeting mechanisms were exemplified by two different values of the modified frequency parameter, with the value for the second peak similar to that for single fin configurations. R.E.P.

A93-20176#
IMPLEMENTATION OF AN EXPLICIT NAVIER-STOKES ALGORITHM ON A DISTRIBUTED MEMORY PARALLEL COMPUTER
STEPHEN SCHERR (USAF, Wright Lab., Wright-Patterson AFB, OH) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by USAF refs
(AIAA PAPER 93-0063)

An efficient parallel implementation of the two-step explicit MacCormack predictor-corrector algorithm for solution of the 3D, laminar Navier-Stokes equations is developed for a distributed memory multiprocessor architecture. Principal design points are a pencilled domain decomposition, utilization of only nearest-neighbor communications, and load balancing. It is shown that performance enhancements from load balancing outweigh penalties due to increased communication times. R.E.P.

A93-20177*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
PARALLEL COMPUTATION OF 3-D NAVIER-STOKES FLOWFIELDS FOR SUPERSONIC VEHICLES
JAMES S. RYAN and SISIRA WEERATUNGA (NASA, Ames Research Center, Moffett Field, CA) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NCC2-505; NAS2-12961)
(AIAA PAPER 93-0064) Copyright

Multidisciplinary design optimization of aircraft will require unprecedented capabilities of both analysis software and computer hardware. The speed and accuracy of the analysis will depend heavily on the computational fluid dynamics (CFD) module which is used. A new CFD module has been developed to combine the robust accuracy of conventional codes with the ability to run on parallel architectures. This is achieved by parallelizing the ARC3D algorithm, a central-differenced Navier-Stokes method, on the Intel iPSC/860. The computed solutions are identical to those from conventional machines. Computational speed on 64 processors is comparable to the rate on one Cray Y-MP processor and will increase as new generations of parallel computers become available. Author

A93-20178*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A SOLUTION SCHEME FOR THE EULER EQUATIONS BASED ON A MULTI-DIMENSIONAL WAVE MODEL
KENNETH G. POWELL (Michigan Univ., Ann Arbor), TIMOTHY J. BARTH (NASA, Ames Research Center, Moffett Field, CA), and IJAZ H. PARPIA (Texas Univ., Arlington) Jan. 1993 16 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0065) Copyright

A scheme for the solution of scalar advection on an unstructured mesh has been developed, tested, and extended to the Euler equations. The scheme preserves a linear function exactly, and yields nearly monotone results. The flux function associated with the Euler scheme is based on a discrete 'wave model' for the system of equations. The wave model decomposes the solution gradient at a location into shear waves, entropy waves and acoustic waves and calculates the speeds, strengths and directions associated with the waves. The approach differs from typical flux-difference splitting schemes in that the waves are not assumed to propagate normal to the faces of the control volumes; directions of propagation of the waves are instead computed from solution-gradient information. Results are shown for three test cases, and two different wave models. The results are compared to those from other approaches, including MUSCL and Galerkin least squares schemes. Author

A93-20179#
A NEW ROTATED UPWIND DIFFERENCE SCHEME FOR THE EULER EQUATIONS
CHET L. LECK and JOHN C. TANNEHILL (Iowa State Univ. of Science and Technology, Ames) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0066) Copyright

A explicit, rotated upwind algorithm has been developed to solve the Euler equations. The upwinding angle for the rotated algorithm is determined by using the local pressure gradient data and the upwind fluxes are computed using Roe's method. A 'refining' procedure is then applied to obtain the final solution which exhibits little or no smearing across a discontinuity. Three test cases were computed to validate the new rotated algorithm. These include (1) a simple oblique shock problem, (2) a simple

shock reflection problem, and (3) supersonic flow into a two-dimensional converging inlet. The computed results are in excellent agreement with the exact solutions and show significant improvement over other rotated upwind schemes. Author

A93-20180#
FLUX LIMITERS IN A ROTATED UPWIND SCHEME FOR THE EULER EQUATIONS
JACK E. HASE and IJAZ H. PARPIA (Texas Univ., Arlington) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0067) Copyright

A method for minimizing the numerical dissipation in a finite volume scheme for the Euler equations of gas-dynamics is presented. The goal is to increase the resolution of flow discontinuities oblique to the grid. The resolution of both shocks and shears is increased. Upwind biased fluxes are computed in two orthogonal directions for each face with Roe's approximate Riemann solver. The upwinding directions are aligned with and perpendicular to the velocity jump direction between each face of adjacent cells. The dissipation associated with upwinding is limited through the use of a function similar to those developed for use with a second order MUSCL reconstruction scheme. This scheme is shown to be similar to a central difference scheme with artificial dissipation. Author

A93-20181#
COMPARISON OF LIMITERS IN FLUX-SPLIT ALGORITHMS FOR EULER EQUATIONS
JAMES N. SCOTT and YANG-YAO NIU (Ohio State Univ., Columbus) Jan. 1993 16 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0068) Copyright

A comparative study of the influence of limiter functions used in explicit MUSCL type flux-split algorithms has been performed for a one-dimensional shock tube problem and a high speed blunt body simulation in both perfect and real gases. These MUSCL type schemes include Steger-Warming and van-Leer flux-vector spliting and Roe flux-difference splitting. An NVD is used to investigate the dissipation and dispersion properties of several limiter functions in the general upwind-biased MUSCL type differing. The emphasis of this study is focused on the influence of limiters on the resolution of expansion fans, contact discontinuities and shock waves in flowfields. Also, the behavior of stability and convergence rate induced by different limiters for hypersonic flow are compared. The computational results indicate that the van Albada limiter is the better choice for shock resolution and stability and convergence rate in both the one-dimensional shock tube problems and the two-dimensional high-speed blunt body flows. Author

A93-20183#
ACCURATE SOLUTION OF THE 2D EULER EQUATIONS WITH AN EFFICIENT CELL-VERTEX UPWIND SCHEME
C.-C. ROSSOW (DLR, Inst. fuer Entwurfsaerodynamik, Braunschweig, Germany) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0071) Copyright

The accuracy and efficiency of a cell vertex upwind scheme are investigated. Upwinding is achieved by an unequal distribution of the transformed flux balances to the vertices of a computational cell. The equations are rotated with respect to the local velocity vector to determine the upwinding directions. The method yields second order accurate steady state solutions and gives very sharp shock resolution for transonic flows. Fourth differences background dissipation is added to ensure convergence, and time integration is performed using a 5-stage Runge-Kutta scheme. Accuracy and efficiency of the scheme are enhanced by several means. The background dissipation is scaled by the appropriate eigenvalues instead of using a scalar. Convergence towards steady state is accelerated by employing upwind implicit residual smoothing, and by the use of the multigrid technique. The scheme yields very accurate results on significantly coarse meshes, which makes its efficiency competitive with that of central differencing schemes using multigrid acceleration. Author

A93-20184#
NUMERICAL PREDICTION OF INSTABILITIES IN TRANSONIC INTERNAL FLOWS USING AN EULER TVD CODE
P. LAFON and J. P. DEVOS (Electricite de France, Direction des Etudes et Recherches, Clamart) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0072) Copyright

This paper deals with the application of a two dimensional TVD Euler code to the prediction of instabilities in internal transonic flows. The numerical procedure is based on the Harten-Yee explicit TVD scheme. Validation results are presented for the shock tube problem and the supersonic step problem. The code is applied to the case of a convergent nozzle exhausting in a rectangular duct. This transonic flow shows different kinds of instabilities. The numerical results can predict some of the observed flow dynamics. Author

A93-20186#
RECEPTIVITY OF THREE-DIMENSIONAL BOUNDARY LAYERS
J. D. CROUCH (Boeing Commercial Airplane Group, Seattle, WA) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0074) Copyright

The receptivity of a three-dimensional boundary layer to cross-flow vortices, both in the presence and in the absence of sound, is analyzed using perturbation methods. The undisturbed mean flow is given by the Falkner-Skan-Cooke solution of the boundary-layer equations for a uniform swept wedge. Distortions of the mean flow are introduced by localized perturbations of the surface geometry leading to steady cross-flow vortices. The amplitude of the steady vortices is given by the product of: the surface-perturbation height, the Fourier transform of the perturbation shape, and the response residue associated with the natural eigenmode. Unsteady cross-flow vortices are generated in the presence of acoustic free-stream disturbances. For unsteady vortices, the disturbance amplitude is given by the product of: the surface-perturbation height, the acoustic amplitude, the transform of the perturbation shape, and the response residue. Results show the receptivity to steady cross-flow disturbances to be dominant for acoustic amplitudes characteristic of flight conditions. Author

A93-20187*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SPATIAL SIMULATION OF BOUNDARY LAYER INSTABILITY - EFFECTS OF SURFACE ROUGHNESS
G. DANABASOGLU, S. BRINGEN (Colorado Univ., Boulder), and C. L. STREETT (NASA, Langley Research Center, Hampton, VA) Jan. 1993 15 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG1-1161; N00014-91-J-1086)
(AIAA PAPER 93-0075) Copyright

The effects of an isolated, two-dimensional roughness element on the spatial development of instability waves in boundary layers are investigated by numerically integrating the two-dimensional, time-dependent, incompressible Navier-Stokes equations, using a finite difference/Chebyshev discretization. It is shown that (high) inviscid frequencies have higher growth rates than Tollmien-Schlichting frequencies, indicating that disturbances growing in the separation zone are controlled by the inviscid instability of the shear layer at the edge of the separation zone. Author

A93-20188*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECT OF MICRON-SIZED ROUGHNESS ON TRANSITION IN SWEPT-WING FLOWS
RONALD H. RADEZTSKY, JR., MARK S. REIBERT, WILLIAM S. SARIC (Arizona State Univ., Tempe), and SHOHEI TAKAGI

(National Aerospace Lab., Tokyo, Japan) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by U.S. Navy refs
(Contract NAG1-937; NAG1-1111)
(AIAA PAPER 93-0076) Copyright

Boundary-layer transition-to-turbulence studies are conducted in the Arizona State University Unsteady Wind Tunnel on a 45-degree swept airfoil. The pressure gradient is designed so that the initial stability characteristics are purely crossflow-dominated. Flow visualization and hot-wire measurements show that the development of the crossflow vortices is influenced by roughness near the attachment-line. Comparisons of transition location are made between a painted surface, a machine-polished surface, and a hand-polished surface. Then, isolated 6 micron roughness elements are placed near the attachment line on the airfoil surface under conditions of the final polish (0.25 micron rms). These elements amplify a centered stationary crossflow vortex and its neighbors, resulting in localized early transition. The diameter, height, and location of these roughness elements are varied in a systematic manner. Spanwise hot-wire measurements are taken behind the roughness element to document the enhanced vortices. These scans are made at several different chord locations to examine vortex growth. Author

A93-20189#

TRANSITION STUDIES FOR SWEPT WING FLOWS USING PSE

M. R. MALIK and F. LI (High Technology Corp., Hampton, VA) Jan. 1993 28 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract F49620-91-C-0014)
(AIAA PAPER 93-0077) Copyright

Linear and nonlinear stability of a model swept-wing boundary layer, subject to crossflow instability, is studied employing parabolized stability equations (PSE). The linear PSE results for stationary disturbances agree well with the results obtained from direct solution of Navier-Stokes equations. Nonlinear development of stationary crossflow vortex is examined for an initial amplitude of 0.1 percent. R.E.P.

A93-20190*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

STABILITY AND TRANSITION ON SWEPT WINGS

GREG STUCKERT (DynaFlow, Inc., Columbus, OH), THORWALD HERBERT (Ohio State Univ., Columbus), and VAHID ESFAHANIAN (DynaFlow, Inc., Columbus, OH) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS2-13513; F49620-92-J-0271)
(AIAA PAPER 93-0078) Copyright

This paper describes the extension and application of the Parabolized Stability Equations (PSE) to the stability and transition of the supersonic three-dimensional laminar boundary layer on a swept wing. The problem formulation uses a general coordinate transformation for arbitrary curvilinear body-fitted computational grids. Some testing using these coordinates is briefly described to help validate the software used for the investigation. The disturbance amplitude ratios as a function of chord position for supersonic (Mach 1.5) boundary layers on untapered, untwisted wings of different sweep angles are then presented and compared with those obtained from local parallel analyses. Author

A93-20191*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

LINEAR STABILITY OF THREE-DIMENSIONAL BOUNDARY LAYERS - EFFECTS OF CURVATURE AND NON-PARALLELISM

M. R. MALIK and P. BALAKUMAR (High Technology Corp., Hampton, VA) Jan. 1993 21 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS1-19299)
(AIAA PAPER 93-0079) Copyright

In this paper we study the effect of in-plane (wavefront) curvature on the stability of three-dimensional boundary layers. It is found that this effect is stabilizing or destabilizing depending upon the sign of the crossflow velocity profile. We also investigate the effects of surface curvature and nonparallelism on crossflow instability. Computations performed for an infinite-swept cylinder show that while convex curvature stabilizes the three-dimensional boundary layer, nonparallelism is, in general, destabilizing and the net effect of the two depends upon meanflow and disturbance parameters. It is also found that concave surface curvature further destabilizes the crossflow instability. Author

A93-20192#

A THEORETICAL APPROACH FOR DESCRIBING SECONDARY INSTABILITY FEATURES IN THREE-DIMENSIONAL BOUNDARY-LAYER FLOWS

T. M. FISCHER, S. HEIN, and U. DALLMANN (DLR, Inst. fuer Theoretische Stroemungsmechanik, Goettingen, Germany) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0080) Copyright

Some characteristic features of the fluctuating part of a three-dimensional boundary layer are described within the framework of a secondary stability theory. Since the stability model provides eigenvalues and eigenfunctions, the frequency and amplification of secondary disturbances and the spatial structures of the rms fluctuation produced by these disturbances are considered. In particular, a high-frequency secondary instability is obtained for amplitudes of the primary stationary vortices larger than about 10 percent. The features of this instability are discussed and compared with those of the low-frequency secondary disturbances. Furthermore, a method which allows to interpret local secondary stability results in case the primary disturbance is strongly amplified is presented. On the basis of this method, the growth of the maximum and minimum values of the streamwise rms fluctuation is calculated and compared with the measured amplification. Author

A93-20195#

QUANTITATIVE LASER VELOCIMETRY MEASUREMENTS IN THE HYPERSONIC REGIME BY THE INTEGRATION OF EXPERIMENTAL AND COMPUTATIONAL ANALYSIS

MARK S. MAURICE (USAF, Wright Lab., Wright-Patterson AFB, OH) Jan. 1993 15 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0089)

An experimental and computational study of a hypersonic inlet flowfield is performed at a freestream Mach number of 5.76 and a Reynolds number of 44.3 million per meter. Laser velocimetry (LV) measurements throughout the flow are compared with the computational prediction, and a technique is presented which identifies and quantifies velocity lag bias of polydispersed seed within LV data. Results show that despite the problem of particle velocity lag within high speed, complex flows, LV measurements can still be used for flow structure analysis and computational code validation. In this case, the developing boundary layer along the inlet ramp is accurately predicted, but the algebraic eddy viscosity model overestimates the turbulence production at the shock wave - boundary layer interactions. Author

A93-20196#

FLOW VISUALIZATION STUDIES ON SIDEWALL EFFECTS IN TWO DIMENSIONAL TRANSONIC AIRFOIL TESTING

NORIKAZU SUDANI, MAMORU SATO, HIROSHI KANDA, and KENICHI MATSUNO (National Aerospace Lab., Tokyo, Japan) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0090) Copyright

The effects of sidewall boundary layers in two-dimensional transonic airfoil testing were investigated using oilflow or liquid crystal visualization techniques. Three different chord models were tested in order to clarify the sidewall effects and to seek a suitable aspect ratio of the airfoil. The oilflow visualization data systematically reveal the surface flow patterns affected by the sidewalls and suggest a minimum aspect ratio for conducting

reliable two-diemensional tests. The results of the liquid crystal visualization also show the three-dimensionality of the transition behavior and the necessity of the high aspect ratio. In addition, investigations on effects of the sidewall boundary-layer suction and application of a sidewall interference correction produce significant results for improvement of airfoil testing by removal of the sidewall effects. Author

A93-20197#
THE PROBLEM OF DYNAMIC STALL SIMULATION REVISITED
LARS E. ERICSSON Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0091) Copyright

An examination of existing literature relative to the problem of dynamic stall simulation reveals that side-wall interference tends to make it more difficult to experience the peaky maximum lift characteristics. Since the peak velocity on the airfoil at stall is several times larger than the freestream velocity, compressibility effects are ordinarily large. Subscale test results are studied against this background of simulation problems. R.E.P.

A93-20199*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE USE OF SUBSCALE MODELS TO PREDICT SELF-INDUCED OSCILLATIONS OF FLIGHT VEHICLES
R. C. NELSON, A. S. ARENA, JR., and D. L. WILLIAMS, II (Notre Dame Univ., IN) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Univ. of Notre Dame refs
(Contract NCA2-513)
(AIAA PAPER 93-0093) Copyright

The suitability of utilizing subscale dynamic wind tunnel experiments to predict wing rock for slender aircraft is presented. As observed in experiments, both flight and wind tunnel, there is significant interaction of the forebody and leading-edge extension vortices. It is concluded that subscale models can be employed to predict high angle of attack dynamic behavior such as wing rock provided proper precautions are taken. R.E.P.

A93-20200#
CIRCULATION CONTROL WING MODEL STUDY
M. E. FRANKE, M. E. PELLETIER, and J. W. TRAINOR (USAF, Inst. of Technology, Wright-Patterson AFB, OH) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0094)

A wind tunnel study of a sting-mounted circulation control wing model is described. The wing model has an elliptical wing section, a rectangular planform, and an aspect ratio of 2.3. Lift is increased by blowing air from a slot along the wing span over the blunt trailing edge. Aerodynamic data are presented for a Reynolds number of 9 x 100,000. The wind tunnel data acquisition and pressure scanning systems are described. Author

A93-20204#
AN EFFICIENT APPROACH TO OPTIMAL AERODYNAMIC DESIGN. I - ANALYTIC GEOMETRY AND AERODYNAMIC SENSITIVITIES
A. VERHOFF, D. STOOKESBERRY, and A. B. CAIN (McDonnell Douglas Corp., Saint Louis, MO) Jan. 1993 15 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0099) Copyright

A technique under development for analytic solution of the 2D steady Euler equations is presented. This method is complemented by a newly developed analytic procedure for representing airfoil geometry. Test results demonstrate an increase in efficiency by more than two orders of magnitude compared to the usual CFD approach utilizing finite geometric perturbations. R.E.P.

A93-20205#
AN EFFICIENT APPROACH TO OPTIMAL AERODYNAMIC DESIGN. II - IMPLEMENTATION AND EVALUATION
D. STOOKESBERRY, A. VERHOFF, and A. B. CAIN (McDonnell Douglas Corp., Saint Louis, MO) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0100) Copyright

An efficient method for optimal aerodynamic design of airfoils is being developed. It is based on the integration of three component elements: (1) analytical representation of the geometry; (2) analytical determination of aerodynamic senitivities based on the Euler equations; and (3) a computational package for optimal design subject to arbitrary constraints. Analytical determination of aerodynamic sensitivities coupled with the analytical geometry representation leads to more than two orders of magnitude cost reduction with respect to the conventional computational fluid dynamics (CFD) approach. Results are presented for a two-dimensional airfoil design to a specified pressure distribution or lift coefficient with design constraints. Comparisons are made with a conventional CFD Euler design method illustrating the efficiency improvement of the analytic method. Author

A93-20300* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CALCULATIONS OF SEPARATED VORTEX FLOWS AT LOW SPEED FOR LOW-ASPECT-RATIO WINGS
C. H. LIU (NASA, Langley Research Center, Hampton, VA) and C.-H. HSU (Vigyan, Inc., Hampton, VA) Sep. 1992 11 p. IUTAM Symposium on Fluid Dynamics of High Angle of Attack, Tokyo, Japan, Sept. 13-17, 1992, Paper refs
(Contract NAS1-18585)

An implicit finite-difference scheme has been developed for solving three-dimensional incompressible Navier-Stokes equations. Computations for complicated vortical flows past several sharp- and round-edged delta and double-delta wings at high angles of attack and sideslip are discussed. Computed results demonstrate the effectiveness of the present method and show good agreement with experimental data. Author

A93-20303#
A MULTI-POINT OPTIMIZATION FOR TRANSONIC AIRFOIL DESIGN
J. O. HAGER, S. EYI, and K. D. LEE (Illinois Univ., Urbana) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 13-20. refs
(AIAA PAPER 92-4681) Copyright

A two-point, aerodynamic design method is presented which improves the aerodynamic performance of transonic airfoils over a range of the flight envelope. It couples an Euler flow solver and a numerical optimization tool. The major limitation of single-point design is the poor off-design performance. Two-point design is used to extend the optimized performance range over more of the desired flight envelope. The method is applied to several transonic flow design points, and the results are compared to single-point design results. The secondary design-points are chosen by varying the angle-of-attack, and the angle-of-attack and Mach-number. The two-point designs perform better than the single-point design over the design-point range. Author

A93-20309*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
IMPROVING THE EFFICIENCY OF AERODYNAMIC SHAPE OPTIMIZATION PROCEDURES
GREG W. BURGREEN, OKTAY BAYSAL, and MOHAMED E. ELESHAKY (Old Dominion Univ., Norfolk, VA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 87-97. refs

(Contract NAG1-1188)
(AIAA PAPER 92-4697) Copyright

The computational efficiency of an aerodynamic shape optimization procedure which is based on discrete sensitivity analysis is increased through the implementation of two improvements. The first improvement involves replacing a grid point-based approach for surface representation with a Bezier-Bernstein polynomial parameterization of the surface. Explicit analytical expressions for the grid sensitivity terms are developed for both approaches. The second improvement proposes the use of Newton's method in lieu of an alternating direction implicit (ADI) methodology to calculate the highly converged flow solutions which are required to compute the sensitivity coefficients. The modified design procedure is demonstrated by optimizing the shape of an internal-external nozzle configuration. A substantial factor of 8 decrease in computational time for the optimization process was achieved by implementing both of the design improvements. Author

A93-20310* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

AERODYNAMIC SHAPE OPTIMIZATION VIA SENSITIVITY ANALYSIS ON DECOMPOSED COMPUTATIONAL DOMAINS

MOHAMED E. ELESHAKY and OKTAY BAYSAL (Old Dominion Univ., Norfolk, VA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 98-109. refs
(Contract NAG1-1188)
(AIAA PAPER 92-4698) Copyright

Direct and iterative method considered to be most applicable to large systems of linear equations arising in discrete sensitivity analysis are assessed. Based on a single-domain grid, computations are performed using a banded matrix solver and an iterative solver, the generalized minimum residual (GMRES) method. The banded matrix solver is found to be generally the most economical method for those applications where the number of right-hand sides is large (i.e., a large number of design variables or a large number of adjoint vectors). For systems of equations that are too large to be solved by direct methods, an approach is proposed whereby the computational domain is divided into small subdomains, and each subdomain is solved separately. V.L.

A93-20344* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

AN APPROXIMATELY FACTORED INCREMENTAL STRATEGY FOR CALCULATING CONSISTENT DISCRETE AERODYNAMIC SENSITIVITY DERIVATIVES

V. M. KORIVI, A. C. TAYLOR, III (Old Dominion Univ., Norfolk, VA), P. A. NEWMAN (NASA, Langley Research Center, Hampton, VA), G. J.-W. HOU (Old Dominion Univ., Norfolk, VA), and H. E. JONES (U.S. Army, Aviation Systems Command, Hampton, VA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 465-478. refs
(AIAA PAPER 92-4746) Copyright

An incremental strategy is presented for iteratively solving very large systems of linear equations, which are associated with aerodynamic sensitivity derivatives for advanced CFD codes. It is shown that the left-hand side matrix operator and the well-known factorization algorithm used to solve the nonlinear flow equations can also be used to efficiently solve the linear sensitivity equations. Two airfoil problems are considered as an example: subsonic low Reynolds number laminar flow and transonic high Reynolds number turbulent flow. V.L.

A93-20416# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

ANALYTICAL FORMULATION OF OPTIMUM ROTOR INTERDISCIPLINARY DESIGN WITH A THREE-DIMENSIONAL WAKE

CHENGJIAN HE (Georgia Inst. of Technology, Atlanta) and DAVID A. PETERS (Washington Univ., Saint Louis, MO) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 1164-1176. refs
(Contract NAG1-710; NAG1-1373; NAG2-462; NAG2-728)
(AIAA PAPER 92-4778) Copyright

An analytical formulation of optimum rotor interdisciplinary design is presented. A finite-state aeroelastic rotor model, coupling generalized dynamic wake with blade finite elements, is applied to perform the optimum rotor blade design for improved aerodynamic performance and vehicle vibration, while a feasible direction nonlinear optimizer, CONMIN, provides the optimization algorithm. The approach features a systematic rotor aeroelastic model which offers an efficient analytical tool, and retains necessary aerodynamic and blade dynamic building blocks for a sufficient rotor dynamic response analysis. The formulation is well suited for an efficient design sensitivity computation without resorting to finite difference, and thus provides a practical design tool. The results show improved rotor aerodynamic performance and reduced hub vibratory loads for the optimized blade as compared to the advanced rotor of reference design. P.D.

A93-20713* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

DESIGN OF A WING SHAPE FOR STUDY OF HYPERSONIC CROSSFLOW TRANSITION IN FLIGHT

A. GODIL (High Technology Corp.; NASA, Langley Research Center, Hampton, VA) and A. BERTELRUD (Analytical Services and Materials, Inc.; NASA, Langley Research Center, Hampton, VA) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 115-130. refs
(Contract NAS1-19299)
Copyright

Computational fluid dynamics methods were used in the design of a wing shape for study of hypersonic crossflow transition in flight. The flight experiment is to be performed on the delta wing of the first stage of a Pegasus launch vehicle as a piggy-back experiment to support boundary-layer stability code development and validation. The design goal is to obtain crossflow-induced transition at 20-40 percent of the chord for a flight Mach number of approximately six. The present paper describes the design and analysis process utilized to obtain desired glove shape. A variety of schemes were used in the design, ranging from simple empirical crossflow correlations to three-dimensional Navier-Stokes codes in conjunction with linear stability/N-factor computations. The sensitivity to various parameters, such as trajectory variations, allowable wing thickness, leading-edge radius and surface temperature, is also discussed. Author

A93-20716* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

NUMERICAL SIMULATION OF JET NOISE

W. R. VAN DALSEM (NASA, Ames Research Center, Moffett Field, CA) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 169-179. refs
Copyright

Jet noise and jet-induced structural loads have become key issues in the design of commercial and military aircraft. Computational Fluid Dynamics (CFD) can be of use in predicting the underlying jet shear-layer instabilities and, in conjunction with classical acoustic theory, jet noise. The computational issues involved in the resolution of high Reynolds number unsteady jet flows are addressed in this paper. Once these jet flows can be accurately resolved, it should be possible to use acoustic theory to extract, for example, the far-field jet noise. An assessment of future work and computational resources required for directly computing far-field jet noise is also presented. Author

A93-20721* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
UNSTEADY TWO- AND THREE-DIMENSIONAL NAVIER-STOKES SIMULATIONS OF MULTISTAGE TURBOMACHINERY FLOWS
K. L. GUNDY-BURLET (NASA, Ames Research Center, Moffett Field, CA) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 231-240. refs
Copyright
The flow-field within an axial flow turbomachine, such as a turbine or compressor, is extremely complex because of three-dimensional features such as hub-corner stall, tip-leakage flows, and airfoil wakes. These flow features interact with each other and with rotor and stator airfoils inducing time-varying forces on the airfoils. These complicated rotor-stator interactions must be understood in order to design turbomachines that are light and compact as well as reliable and efficient. Two codes, STAGE-2 and STAGE-3, have been developed to compute these unsteady rotor-stator interaction flows in multistage turbomachines. An implicit, thin-layer Euler/Navier-Stokes zonal algorithm is used to compute the unsteady flow-field within both turbine and compressor configurations. Results include surface pressures and wake profiles for two-dimensional turbine and compressor configurations and surface pressures for a three-dimensional single-stage turbine configuration. The results compare well with experimental data and other unsteady computations. Author

A93-20729
MASSIVELY PARALLEL AERODYNAMIC SHAPE OPTIMIZATION
C. E. OROZCO and O. N. GHATTAS (Carnegie Mellon Univ., Pittsburgh, PA) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 311-320. Research supported by Carnegie Mellon Univ. refs
(Contract NSF DDM-90-09597; NSF DDM-91-14678)
Copyright
We consider the problem of finding the shape of an airfoil which produces a pressure distribution closest to a desired one. The flow is modeled by the nonlinear potential equations of compressible flow. The problem is formulated as an optimization problem constrained by a discrete approximation to a nonlinear boundary value problem. We present a new parallel infeasible path method for this class of optimization problem. The method is based on a null space representation tailored to the structure of the constraint Jacobian matrix. The resulting null space projections formally involve inverses of the stiffness matrix. The algorithm requires only two stiffness matrix solves per optimization iteration, in contrast to a conventional path-following method, which resolves the full physics at each iteration. The algorithm has been implemented on a CM-2, and requires no new data structures or communication patterns beyond those needed for numerical solution of the boundary value problem. We discuss numerical evidence for the superiority of the new method relative to a conventional path-following approach. Author

A93-20738
FLIGHT VEHICLE AERODYNAMICS CALCULATED BY A GALERKIN FINITE ELEMENT/FINITE DIFFERENCE METHOD
M. HOLT (California Univ., Berkeley) and A. J. MEADE, JR. (Rice Univ., Houston, TX) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 413-421. refs
Copyright
Results are presented to illustrate the feasibility of calculating compressible boundary layer flow about a sharp circular cone by a finite element/finite difference method, the semi-discrete Galerkin (SDG) method. The finite element discretization across the layer yields a system of first order ordinary differential equations in the circumferential direction. The circumferential derivatives are solved by an implicit and non-iterative finite difference marching scheme. The SDG method promises to be fast, accurate and computationally efficient. The resulting computer program can be coupled to any existing inviscid flow solver (portability). Experimental and numerical results are presented for laminar compressible flow past a pointed circular cone at an angle of attack of 4 deg and at a Mach number of 7.3. All numerical solutions assume an attached laminar boundary layer. Author

A93-20741
AIR FLOW DYNAMICS AROUND AN AEROFOIL BY THE STABILIZED FINITE DIFFERENCE METHOD
T. ARATANI (Hiroshima Prefectural Univ., Syobara, Japan) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 437-442. refs
Copyright
A high performance computing scheme to visualize air flow dynamics around an aerofoil is developed, based on the finite difference method with stabilizing devices. A mass diffusion term is added to the equation of continuity to stabilize the finite difference equation. The time derivative of kinetic energy in the energy balance equation is assumed to be replaced by the time derivative of the pressure, to avoid the tedious iteration for the pressure term. The scheme is applied for two-dimensional compressible flow on an aerofoil in unsteady state. Numerical integration has been executed by a microcomputer with i486DX CPU at 40 MHz, on my compiler, for 200 x 500 mesh nodes, and the result is graphically displayed. The velocity vector pattern shows that the ground effect works to stretch the effective area of the aerofoil. Author

A93-20802
INVESTIGATION OF THE DYNAMIC INFLOW'S INFLUENCE ON ROTOR CONTROL DERIVATIVES
XIAOGU ZHANG and JINSONG BAO (Nanjing Aeronautical Inst., China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956) vol. 24, no. 5 Oct. 1992 p. 485-495. In Chinese. refs
This paper develops a method accounting for dynamic inflow model to analyze the rotor control response. This method can be used to calculate rotor force, rotor moments, and control derivatives. Rotor model tests on the rotor model test stand are performed to measure rotor static control derivatives in hover. This paper verifies the dynamic inflow effects and clarifies preliminarily the influence of dynamic inflow through comparison analysis of the measured and the predicted data (with and without dynamic inflow). A simplified method is used to investigate the influence of dynamic inflow on the different rotor configurations, including a hingeless rotor and an articulated rotor. Author

A93-20804
EXPERIMENTAL STUDY OF DYNAMIC STALL ON AN OSCILLATING AIRFOIL
RUIYUAN TANG, XIANMING HUA, and YONGJIAN WU (Nanjing Aeronautical Inst., China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956) vol. 24, no. 5 Oct. 1992 p. 506-512. In Chinese. refs
Experimental study of dynamic stall on the oscillating airfoil NACA0012 is done by means of the force measurement method. Some special questions and approaches to the force measurement method on each main link of the dynamic stall tests are discussed. The results measured by using this method are in good agreement with those measured by using the traditional pressure measurement method. The good experimental results show that the force measurement method may be considered as a new approach to the experimental study of dynamic stall on the oscillating airfoil. Author

A93-20806
ESTIMATION OF THE MAXIMUM VALUES OF INSTANTANEOUS DISTORTION INDEX DC SUB THETA
DEWANG LIANG and SHIYING ZHANG (Nanjing Aeronautical Inst., China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956) vol. 24, no. 5 Oct. 1992 p. 521-529. In Chinese. refs
The statistical method for estimating the maximum instantaneous distortion in Liang and Zhang (1984) is extended to estimate the maximum values of DC sub theta in which the operation of peak values of dynamic pressures are involved. The effects of the correlation between fluctuating pressures and the amplitude probability density of the instantaneous distortion on

the estimation are discussed. Comparison between the estimated values and the experimental results shows that the newly developed method can accurately estimate the maximum value of the instantaneous distortion involving the operation of peak values of dynamic pressures, such as the distortion index. P.D.

A93-20909
A NEW TECHNIQUE FOR ANALYSIS OF UNSTEADY AERODYNAMIC RESPONSES OF CASCADE AIRFOILS WITH BLUNT LEADING EDGE. I - THEORY
KEN-ICHI FUNAZAKI and SATOSHI KAKUDATE Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58 March 1992 p. 728-735. In Japanese. refs
Copyright
A new technique has been developed, based on the technique proposed by Goldstein (1978), in order to analyze unsteady aerodynamic responses of cascade airfoils subjected to incident wakes. One of the important features of this technique is the introduction of the additional perturbation potential for the purpose of preventing the solution being indeterminate due to the singular behavior of the unsteady perturbed velocities around the blunt leading edge. In this paper, the main focus is placed on the theoretical development of the technique, and some simple cases of numerical calculations with no stagger angle are made in order to show the validity of our method. Author

A93-20919
BLADE LOADING OF TRANSONIC CIRCULAR CASCADE DIFFUSER
HIROSHI HAYAMI, MASAYUKI SAWAE, TAKANORI NAKAMURA, and NOBUMASA KAWAGUCHI Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58 June 1992 p. 1776-1779. In Japanese. refs
Copyright
A low-solidity circular cascade, conformally transformed from a high-stagger linear cascade of double-circular-arc vanes with solidity 0.69, was tested as a part of the diffuser system of a transonic centrifugal compressor, and the blade loading of the cascade was investigated by means of pressure measurement around the vane. The experimental data for the lift-coefficient of the vane were almost on a single straight line when plotted against angle-of-attack for a wide range of Mach numbers and flow angles. The maximum lift-coefficient reached about 1.5 and the vane functioned well even near the surge condition of the compressor. Author

A93-20923
TRANSITIONAL CHARACTERISTICS OF VORTICES ISSUED FROM A BODY WHICH CREATES ASYMMETRIC FLOW FIELD - IN A CASE OF THIN SYMMETRICAL AIRFOIL WITH ANGLE OF ATTACK UNDER ROTATIONAL OSCILLATION OF SMALL AMPLITUDE
HIROYUKI HANIU, HIROSHI SAKAMOTO, YOSHIHIRO OBATA, and TAKASHI SHIRAGA Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58 June 1992 p. 1997-2002. In Japanese. refs
Copyright
An experimental study was carried out on vortices issued from a thin symmetrical airfoil with angle of attack under rotational oscillation of small amplitude. The experiments were conducted in a hydraulic flume using Laser Doppler Velocimetry (LDV) and ensemble averaging technique to map the unsteady velocity field about the vortex generating region. From this study, transitional characteristics of vortices issued from a body which creates asymmetric flow field became clear. Especially, the reducing mechanism of circulation due to different flow characteristics between the upper and lower vortices became clear from investigation of time variation of the vorticity and shear velocity distributions. Author

A93-20924
NUMERICAL ANALYSIS OF TWO-DIMENSIONAL FLOWS AROUND ELLIPTIC WINGS ABOVE A FLAT PLATE
TSUYOSHI ENDOH Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58 June 1992 p. 2003-2009. In Japanese. refs
Copyright
This paper reports on flows around two-dimensional elliptic wings which are linearly arranged above a flat plate. To solve two-dimensional time-dependent incompressible Navier-Stokes equations which use a body-fitted curvilinear coordinate system, a numerical solution method has been developed, and the method has been applied to the flows around 25 percent thickness elliptic wing cascades slanted at an angle of attack 15 deg at a Reynolds number of 1.6 x 1000. Those wings are linearly arranged at an equal distance above a flat plate. This paper presents a number of numerical solutions for streamlines, vorticity profiles, lift, drag, and pressure distributions. The lift and the drag almost regularly fluctuate with time, and the flow rates through each passage also regularly fluctuate. The present studies have been conducted as basic research into the mechanism of blowing snow off a road. Author

A93-20929
PERFORMANCE ANALYSIS OF SUPERSONIC THROUGH-FLOW FAN BY THE LIFTING SURFACE THEORY. I - DISTURBANCE FLOW FIELD AND DETERMINATION OF BLADE LOADINGS
MASANOBU NAMBA and TOSHIYA HANADA Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58 April 1992 p. 1142-1149. In Japanese. refs
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The purpose of the present study, which is composed of two parts, is to predict analytically the steady performance of a supersonic through-flow fan in terms of design parameters. It is assumed that the fan cascade operates at supersonic axial velocity with a small angle of attack, camber, and thickness. In this report, the linearized lifting surface theory for a rotating annular cascade on the basis of the finite radial eigenfunction series approximation developed by Namba (1972) is extended to the supersonic through-flow fan model. Expressions of the disturbance flowfield are derived, and the integral equation for the steady loading is numerically solved. The fundamental features of the blade surface pressure distribution dependent on the blade profile are demonstrated. Author

A93-20930
TWO-DIMENSIONAL CASCADE TESTS OF MCA BLADES IN THE HIGH TRANSONIC MACH NUMBER REGION. V - EFFECT OF SPACE/CHORD RATIO ON THE PARAMETERS OF CASCADE PERFORMANCE
HAJIME SAKAGUCHI and SUSUMU TAKAMORI Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58 April 1992 p. 1158-1164. In Japanese. refs
Copyright
Two-dimensional cascade tests of multiple circular arc (MCA) blades with a camber angle of 56 deg were carried out in the inlet Mach number range 0.4-1.2 using different cascade geometries and incidence angles. Test results are used to clarify the effect of the space/chord ratio on the inlet Mach number characteristics, on the relationship between the incidence angle and cascade performance at inlet Mach 0.9-1.1, and on the stall and reference incidence angles. Attention is also given to the relationship between the incidence angle and the critical inlet Mach number for space/chord ratios of 0.4, 0.6, and 0.8 and the relationship between the space/chord ratio and the deviation angle at the optimal incidence angle. V.L.

A93-20933
STREAMWISE VARIATION OF MEAN VELOCITY FIELD FOR THE TURBULENT BOUNDARY LAYER INTERACTING WITH CONTROLLED LONGITUDINAL VORTEX ARRAYS
HIDEO OSAKA and CHIHARU FUKUSHIMA Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58 April 1992 p. 1289-1296. In Japanese. refs
Copyright

Detailed flow measurements for a planar turbulent boundary layer interacting with artificially generated trailing vortex arrays in a free stream are presented for five cases with independently varying spanwise periodicities of the longitudinal vortex arrays, L/S, and ratios of the longitudinal vortex scale to the boundary layer scale. A spanwise transport of streamwise momentum due to pairs of counterrotating secondary flows is shown to exist within the boundary layer. This gives rise to spanwise periodic variation corresponding to the spanwise spacing of airfoil elements which is persistently maintained in the far downstream region. The role of the L/S value in the distortion process is discussed. V.L.

A93-20934
STUDY ON THE NUMERICAL PROBLEM OF THE BOUNDARY ELEMENT METHOD IN ANALYSIS OF FLOW AROUND A THREE-DIMENSIONAL WING-BODY
SHIKO RYO Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58 April 1992 p. 1303-1308. In Japanese. refs
Copyright
In the boundary element method, accuracy in integration of singular integrands is very important, especially in the case of a very thin, close boundary with complex curvatures, such as a marine propeller. This paper proposes a method for accurate integration of singular integrals in case of the complex boundary mentioned above. The effects induced by the location of wake, length and mesh division of wake for the analysis of lifting body are also presented. Author

A93-21042* National Aeronautics and Space Administration, Washington, DC.
VISCOUS AND INVISCID INSTABILITIES OF A TRAILING VORTEX
ERNST W. MAYER and KENNETH G. POWELL (Michigan Univ., Ann Arbor) Journal of Fluid Mechanics (ISSN 0022-1120) vol. 245 Dec. 1992 p. 91-114. refs
(Contract NGT-50545)
Copyright
The linear stability of the trailing line vortex model of Batchelor (1964) is studied using a spectral collocation and matrix eigenvalue method. The entire unstable region in the swirl/axial wavenumber parameter space is mapped out for various azimuthal wavenumbers for both the inviscid and viscous stability problem. The results of the study provide a direct numerical validation of the large-azimuthal-wavenumber asymptotic analysis of Leibovich and Stewartson (1983). It is shown that accurate results are obtained up to azimuthal wavenumbers of 10,000 and greater, and the agreement with the asymptotic theory is excellent. V.L.

A93-21102*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A COMPARISON OF THE PREDICTIVE CAPABILITIES OF SEVERAL TURBULENCE MODELS USING UPWIND AND CENTRAL-DIFFERENCE COMPUTER CODES
CHRISTOPHER L. RUMSEY and VEER N. VATSA (NASA, Langley Research Center, Hampton, VA) Jan. 1993 17 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0192) Copyright
Four turbulence models are described and evaluated for transonic flows using the upwind code CFL3D and the central-difference code TLNS3D. In particular, the effects of recent modifications to the half-equation model of Johnson-King are explored in detail, and different versions of the model are compared. This model can obtain good results for both two-dimensional (2D) and three-dimensional (3D) separated flows. The one-equation models of Baldwin-Barth and Spalart-Allmaras perform well for separated airfoil flows, but can predict the shock too far forward at the outboard stations of a separated wing. The equilibrium model of Baldwin-Lomax predicts the shock location too far aft for both 2D and 3D separated flows, as expected. In general, all models perform well for attached or mildly separated flows. Author

A93-21103*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NEAR WAKE STRUCTURE FOR A GENERIC ASTV CONFIGURATION
VIRENDRA K. DOGRA (Vigyan, Inc., Hampton, VA), JAMES N. MOSS, and JOSEPH M. PRICE (NASA, Langley Research Center, Hampton, VA) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS1-19237)
(AIAA PAPER 93-0271)
Results of a numerical study are presented for hypersonic low-density flow about a 70-deg blunt cone using the direct simulation Monte Carlo method. Particular emphasis is given to the near wake flow and its sensitivity to rarefaction and other parametric variations. The flow conditions simulated are attainable in existing low-density hypersonic wind tunnels; that is, Mach 20 nitrogen flow encompassing freestream Knudsen numbers of 0.03 to 0.001. A stable vortex forms in the near wake at and below a freestream Knudsen number of 0.01 and the size of the vortex increases with decreasing freestream Knudsen number. The base region of the flow remains in thermal nonequilibrium for all cases. There is no formation of a lip separation shock or a distinct wake shock at these rarefied conditions. Author

A93-21106*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AIR/HELIUM GROUND-TEST SIMULATION PERTINENT TO THE DEFINITION OF SLENDER BODY HYPERSONIC AERODYNAMICS
W. C. WOODS and R. A. THOMPSON (NASA, Langley Research Center, Hampton, VA) Jan. 1993 16 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0318) Copyright
The capability of air/helium simulations pertinent to the definition of slender body hypersonic aerodynamics is tested, using exact inviscid analytical comparisons to characterize the Mach number and bluntness effects. Comparisons are made with experiments conducted from the 1960s through the 1980s. The results indicate no general rule for air/helium simulation. A feasibility for obtaining sufficient simulation for many types of aero/fluid dynamic studies is demonstrated. I.S.

A93-21107*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A GRIDLESS EULER/NAVIER-STOKES SOLUTION ALGORITHM FOR COMPLEX-AIRCRAFT APPLICATIONS
JOHN T. BATINA (NASA, Langley Research Center, Hampton, VA) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0333) Copyright
The development of a gridless computational fluid dynamics (CFD) method for the solution of the two- and three-dimensional Euler and Navier-Stokes equations is described. The method uses only clouds of points and does not require that the points be connected to form a grid as a necessary in conventional CFD algorithms. The gridless CFD approach appears to resolve the inefficiencies encountered with structured or unstructured grid methods, and consequently offers great potential for accurately and efficiently solving viscous flows about complex aircraft configurations. The method is described in detail and calculations are presented for standard Euler and Navier-Stokes cases to assess the accuracy and efficiency of the capability. Author

A93-21111*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SUBSONIC STATIC AND DYNAMIC STABILITY CHARACTERISTICS OF THE TEST TECHNIQUE DEMONSTRATOR NASP CONFIGURATION
RICHMOND P. BOYDEN, DAVID A. DRESS, CHARLES H. FOX, JR., JARRETT K. HUFFMAN, and CHRISTOPHER I. CRUZ (NASA, Langley Research Center, Hampton, VA) Jan. 1993 18 p.

AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0519) Copyright

The paper describes the procedure used for and the results obtained of wind-tunnel tests of the National Aerospace Plane (NASP) configuration, which were conducted in the NASA Langley Research Center High Speed Tunnel using a blended body NASP configuration designed by the research center. Static and dynamic stability characteristics were measured at Mach numbers 0.3, 0.6, and 0.8. In addition to tests of the baseline configuration, component buildup tests with a canard surface and with a body flap were carried out. Results demonstrated a positive static stability of the baseline configuration, except at the higher angles of attack at Mach 0.8. A good agreement was found between the inphase dynamic parameters and the corresponding static data. I.S.

A93-21113*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

COMPUTATIONAL ANALYSIS OF HYPERSONIC SHOCK WAVE/WALL JET INTERACTION

GREGORY L. MEKKES (Analytical Services and Materials, Inc., Hampton, VA) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS1-19320)
(AIAA PAPER 93-0604) Copyright

The purpose of this study is to investigate the CFD code General Aerodynamic Simulation Program (GASP) for application to a specific scramjet combustor phenomenon, that of an adverse pressure gradient caused by an oblique shock wave impinging upon a wall cooling film. The basis of this investigation is data available from an existing experimental study, which includes wall pressure, wall heat transfer, and schlieren photographs. This experimental study was conducted at a nominal Mach number of 6.0 in the Calspan 48-inch shock tunnel. The particular case of interest generates flow separation at the shock impingement point. Two algebraic turbulence models, the Baldwin-Lomax model and the Goldberg model, are considered for this computational study. Resultant computational wall pressure and heat transfer for both turbulence models are compared with experimental data. The Goldberg turbulence model provides a more accurate prediction of the recirculation region, and as a result, a better comparison with the experimental data. Author

A93-21116# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

SPATIAL ADAPTATION PROCEDURES ON TETRAHEDRAL MESHES FOR UNSTEADY AERODYNAMIC FLOW CALCULATIONS

RUSS D. RAUSCH (Purdue Univ., West Lafayette, IN), JOHN T. BATINA (NASA, Langley Research Center, Hampton, VA), and HENRY T. Y. YANG (Purdue Univ., West Lafayette, IN) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NGT-50406)
(AIAA PAPER 93-0670) Copyright

Spatial adaptation procedures for the accurate and efficient solution of steady and unsteady inviscid flow problems are described. The adaptation procedures were developed and implemented within a three-dimensional, unstructured-grid, upwind-type Euler code. These procedures involve mesh enrichment and mesh coarsening to either add points in high gradient regions of the flow or remove points where they are not needed, respectively, to produce solutions of high spatial accuracy at minimal computational cost. The paper gives a detailed description of the enrichment and coarsening procedures and presents comparisons with experimental data for an ONERA M6 wing and an exact solution for a shock-tube problem to provide an assessment of the accuracy and efficiency of the capability. Steady and unsteady results, obtained using spatial adaptation procedures, are shown to be of high spatial accuracy, primarily in that discontinuities such as shock waves are captured very sharply. Author

A93-21117*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

DEVELOPMENT OF A FLEXIBLE AND EFFICIENT MULTIGRID-BASED MULTIBLOCK FLOW SOLVER

VEER N. VATSA (NASA, Langley Research Center, Hampton, VA), MARK D. SANETRIK (Analytical Services and Materials, Inc., Hampton, VA), and EDWARD B. PARLETTE (Vigyan, Inc., Hampton, VA) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0677) Copyright

A multigrid-based numerical scheme for solving the Navier-Stokes and Euler equations on block-structured grids is presented for flows over complex aircraft configurations. Self-consistency checks are conducted to ascertain that the multiblock code reproduces previously known solutions from single-block codes by splitting a single-block grid into multiple blocks. The newly-developed multiblock code maintains multigrid performance of an equivalent single-block code. R.E.P.

A93-21119*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

TRANSONIC SHOCK OSCILLATIONS CALCULATED WITH A NEW INTERACTIVE BOUNDARY LAYER COUPLING METHOD

JOHN W. EDWARDS (NASA, Langley Research Center, Hampton, VA) Jan. 1993 15 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0777) Copyright

A new viscous-inviscid interactive coupling method is described with the aim of allowing time-accurate computation of unsteady transonic flows involving separation and reattachment. A lag-entrainment integral boundary layer method is used in conjunction with a transonic small disturbance potential code. The solutions are coupled with a novel variable gain, integral control method for the boundary layer displacement thickness. Efficient and robust computations of steady and unsteady separated flows, including steady separation bubbles and self-excited shock-induced oscillations, are presented. The buffet onset boundary for the NACA 0012 airfoil is accurately predicted and shown computationally to be a Hopf bifurcation. Shock-induced oscillations are also presented for the 18 percent thick circular arc airfoil. The oscillation onset boundaries and frequencies are accurately predicted, as is the experimentally observed hysteresis of the oscillations with Mach number; this latter stability boundary is identified as a jump phenomenon. Author

A93-21218

THE MODELLING OF AERODYNAMIC FLOWS BY SOLUTION OF THE EULER EQUATIONS ON MIXED POLYHEDRAL GRIDS

A. J. PEACE and J. A. SHAW (Aircraft Research Association, Ltd., Bedford, United Kingdom) International Journal for Numerical Methods in Engineering (ISSN 0029-5981) vol. 35, no. 10 Dec. 1992 p. 2003-2029. Research supported by Ministry of Defence Procurement Executive refs
Copyright

In this paper, an algorithm for obtaining solutions to the compressible Euler equations on mixed polyhedral grids is described. These grids, which are, in general, composed of hexahedral, pentahedral and tetrahedral elements, are used in the modelling of aerodynamic flows over complex three-dimensional geometries. The hexahedra are grouped into regular blocks, while the other elements are part of irregular grid regions, giving rise to the term 'hybrid grid approach'. The interconnection of the grid elements is defined by an efficient data structure, which supplies the required information to drive the Euler algorithm. In fact, cell-vertex and cell-center spatial discretization variants of this algorithm are detailed, along with an explicit time-marching scheme for obtaining steady-state solutions. Results on two geometrically simple configurations provide an evaluation of these solution techniques, while the focus on a third, complex configuration, demonstrates the potential of the method in addressing the flow over general aircraft geometries. Author

A93-21330* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
WORKSHOP REPORT - A VALIDATION STUDY OF NAVIER-STOKES CODES FOR TRANSVERSE INJECTION INTO A MACH 2 FLOW
DEAN R. EKLUND (Analytical Services and Materials, Inc., Hampton, VA), G. B. NORTHAM (NASA, Langley Research Center, Hampton, VA), J. C. MCDANIEL (Virginia Univ., Charlottesville), and CLIFF SMITH (CFD Research Corp., Huntsville, AL) Oct. 1992 17 p. JANNAF, Combustion Meeting, 29th, Hampton, VA, Oct. 19-23, 1992, Paper refs
(Contract NAS1-19320)
A CFD (Computational Fluid Dynamics) competition was held at the Third Scramjet Combustor Modeling Workshop to assess the current state-of-the-art in CFD codes for the analysis of scramjet combustors. Solutions from six three-dimensional Navier-Stokes codes were compared for the case of staged injection of air behind a step into a Mach 2 flow. This case was investigated experimentally at the University of Virginia and extensive in-stream data was obtained. Code-to-code comparisons have been made with regard to both accuracy and efficiency. The turbulence models employed in the solutions are believed to be a major source of discrepancy between the six solutions. Author

A93-21656
MEASURED THRUST LOSSES ASSOCIATED WITH SECONDARY AIR INJECTION THROUGH NOZZLE WALLS
DAVID AZEVEDO (Pratt & Whitney Group, West Palm Beach, FL) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 43-50. Previously cited in issue 17, p. 2853, Accession no. A91-41734 refs
Copyright

A93-21658
GRID GENERATION FOR THREE-DIMENSIONAL TURBOMACHINERY GEOMETRIES INCLUDING TIP CLEARANCE
ANTON H. BASSON, ROBERT F. KUNZ, and BUDUGUR LAKSHMINARAYANA (Pennsylvania State Univ., University Park) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 59-66. Previously cited in issue 18, p. 3068, Accession no. A91-44209 Research supported by Univ. of Stellenbosch refs
(Contract DAAL03-86-G-0044; NSF MSM-86-0009P; NSF CBT-90-015P)
Copyright

A93-21662
CASCADE FLOW CALCULATIONS BY A MULTIGRID EULER METHOD
FENG LIU and ANTONY JAMESON (Princeton Univ., NJ) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 90-97. Research supported by DARPA and IBM Corp. refs
(Contract N00014-89-J-1366; N00014-86-K-0759)
Copyright
An explicit finite-volume method for the Euler equations with multigrid is presented for calculating cascade flows. The method is validated against theoretical test cases of the Hobson shock-free impulse cascade and a supersonic wedge cascade. Results for a VKI turbine cascade and a low-pressure turbine cascade are presented and compared with experimental data. Isentropic Mach number distributions on blade surfaces show good agreement with experiments at design conditions, whereas, discrepancy exists at off-design conditions due to flow separation. With equal efficiency the method is also able to capture qualitative features of secondary flow due to inlet side-wall boundary layers. Author

A93-21669
INVESTIGATION OF A TWO-DIMENSIONAL SCRAMJET INLET, FREESTREAM M = 8-18 AND TSUB 0 = 4100 K
M. A. S. MINUCCI (Centro Tecnico Aeroespacial, Instituto de Estudos Avancados, Sao Jose Dos Campos, Brazil) and H. T. NAGAMATSU (Rensselaer Polytechnic Inst., Troy, NY) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 139-145. Previously cited in issue 07, p. 968, Accession no. A91-21333 Research supported by Brazilian Air Force refs
Copyright

A93-21677
THE SUPPRESSION OF SINGLE-FIN BUFFETING USING TANGENTIAL LEADING EDGE BLOWING ON A DELTA WING
D. E. BEAN, N. J. WOOD, and D. G. MABEY (Bath Univ., United Kingdom) Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering (ISSN 0954-4100) vol. 206, no. G2 1992 p. 93-104. refs
Copyright
The application of tangential leading edge blowing to reduce levels of single-fin buffeting has been studied. The tests were performed in a 2.1 m x 1.5 m wind tunnel using two cropped 60-deg delta wings. To measure the buffet excitation, a rigid fin instrumented with miniature differential pressure transducers was used. It was observed that the leading edge blowing modified the leading edge vortices by reducing the 'effective angle of attack' of the vortex. Blowing at a constant rate shifted the buffet excitation and response to higher angles of attack. Flow visualization confirmed that the mechanism at peak buffeting had not changed, but had been merely shifted. It has been shown that the use of an optimum blowing program could completely suppress the buffeting response. Author

A93-21719
UNSTEADY EFFECTS OF CAMBER ON THE AERODYNAMIC CHARACTERISTICS OF A THIN AEROFOIL MOVING NEAR THE GROUND
M. F. ZEDAN and A. O. NUHAIT (King Saud Univ., Riyadh, Saudi Arabia) Aeronautical Journal (ISSN 0001-9240) vol. 96, no. 959 Nov. 1992 p. 343-350. refs
Copyright
The effect of camber on the aerodynamic characteristics of an infinitely thin aerofoil approaching the ground is studied using a numerical model that accounts for the unsteady nature of the flow. The wake is computed as a part of the solution and the image technique is used to account for ground effects. The results indicate that relative deviations of lift and moment coefficients, from corresponding values far from ground, decrease as the camber ratio or angle of attack increases. Moving the location of maximum camber backward has a similar effect. Meanlines of NACA 4-digit series showed smaller deviations compared to NACA 6-digit series meanlines. Increasing camber ratio or moving maximum camber backward causes the wake trajectory to be lower. The steady ground-effect approach is inaccurate and may give erroneous results for plates with high camber ratios at small angles of attack, especially near the ground. Author

A93-21720
THE PREDICTION OF RIBLET BEHAVIOUR WITH A LOW-REYNOLDS NUMBER K-EPSILON MODEL
B. E. LAUNDER and S.-P. LI (Univ. of Manchester Inst. of Science and Technology, United Kingdom) Aeronautical Journal (ISSN 0001-9240) vol. 96, no. 959 Nov. 1992 p. 351-355. Research supported by British Council and Northwestern Polytechnic Univ. refs
(Contract SERC-GR/E/77039)
Copyright
A two-equation turbulence model-based computational examination has been conducted of flow in the vicinity of riblets that are confined within the nearly constant-stress near-wall sublayer. While idealized blade-shaped riblets showed larger levels of drag reduction than hitherto reported, the more common triangular-profile riblets yielded results comparable to those of experiments. Attention is given to anomalies that arise between computational and experimental results; these indicate an insufficient sensitivity of the equation to 3D straining in the low-Reynolds number region, while the use of an isotropic viscosity model enforces zero-boundary circulation near the riblets. O.C.

A93-21721
HIGH MACH NUMBER DYNAMIC STABILITY OF BLUNT SLENDER CONES AT ANGLE OF ATTACK
M. KHALID (National Research Council of Canada, Ottawa) Aeronautical Journal (ISSN 0001-9240) vol. 96, no. 959 Nov. 1992 p. 356-359. refs
Copyright
The dynamic stability of blunt cones at angles of attack and high supersonic Mach numbers has been investigated along lines similar to the pointed cone solution derived by the present author. The steady pressure distribution on a blunt cone is complemented with a first and second order azimuth contribution resulting from an angle of attack displacement. The unsteady perturbation is then superimposed on the steady solution by accounting for the stream-line deflection in an oscillating flow. The closed form expressions obtained for the dynamic stability of blunt cones reduce to their pointed cone counterparts once the bluntness parameter is equated to zero. The comparison between the theoretical and measured results is quite encouraging. Author

A93-21737
LIFT ENHANCEMENT OF GROUND-EFFECT WING. I - RESULTS OF SCREENING TESTS OF VARIOUS CONCEPTS
TAKENORI MATSUBARA, MASANORI TASHIMO, FUMIO KURE, NOBUYUKI YAMAGUCHI, and TOSHIKAZU OHWAKI Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58, no. 552 Aug. 1992 p. 2456-2463. In Japanese. refs
Copyright
In order to increase the lift capability and/or to reduce take-off speed of a wing-in-ground effect craft, it is necessary to increase the lift coefficient of the wing in the ground effect. For this purpose, screening tests were conducted by applying various methods of lift enhancement to a ground-effect wing model. A lift coefficient of nearly 2 was obtained with a slotted airfoil system consisting of three slots and four airfoil elements. Longitudinal stability was recognized as an important factor. Author

A93-21738
LIFT ENHANCEMENT OF GROUND-EFFECT WING. II - EXPERIMENTAL INVESTIGATION OF THE POWER AUGMENTED RAM WING IN GROUND EFFECT THROUGH THE WIND TUNNEL
TAKENORI MATSUBARA, MASANORI TASHIMO, FUMIO KURE, NOBUYUKI YAMAGUCHI, and TOSHIKAZU OHWAKI Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58, no. 552 Aug. 1992 p. 2464-2471. In Japanese. refs
Copyright
In order to increase the lift capability and/or to reduce take-off speed of a wing-in-ground effect craft, it is necessary to increase the lift coefficient of the wind in the ground effect. For this purpose, experimental investigation has been made to evaluate the power augmented ram wing with forward -mounted propulsion through a low-speed wind tunnel. A lift coefficient above 3 was obtained by the powered ground effect. However, it was recognized that longitudinal stability should be addressed. Author

A93-21863
CONVENTIONAL SKIN FRICTION MEASUREMENT TECHNIQUES FOR STRONGLY PERTURBED SUPERSONIC TURBULENT BOUNDARY LAYERS
D. R. SMITH, E. M. FERNANDO, J. F. DONOVAN, and A. J. SMITS (Princeton Univ., NJ) European Journal of Mechanics, B/Fluids (ISSN 0997-7546) vol. 11, no. 6 1992 p. 719-740. refs
(Contract AF-AFOSR-88-0120)
Copyright
Two methods for determining wall friction in strongly perturbed supersonic turbulent boundary layers were compared. The two methods were found to agree well when the velocity profile displayed a region of logarithmic variation in the transformed plane. The best agreement was found in comparisons of the wall friction rather than the skin friction coefficient which requires determining boundary layer edge conditions. Author

A93-21921
HOLOGRAPHIC INTERFEROMETRIC INVESTIGATION OF SHOCK WAVE INTERACTION WITH A RAMP
S. M. TIENG, K. T. CHANG, and F. M. YU (National Cheng Kung Univ., Tainan, Taiwan) Shock Waves (ISSN 0938-1287) vol. 2, no. 3 1992 p. 133-138. refs
Copyright
The internal flowfield including shock reflections structure inside a 2D half inlet model was examined by a double exposure holographic interferometry using a Q-switched pulse laser. The interferograms give detailed flow visualization pictures. The structures of regular reflection, lambda reflection and Mach reflection in the inlet channel were observed. From the analysis of fringe patterns, the quantitative distributions of flow density, pressure and Mach number of the internal flowfield have been reconstructed. The boundary layer thickening and separation in the case of lambda reflection and the Mach stem in the case of Mach reflection were clearly demonstrated in the holographic fringe patterns. The results show that the shock interactions with the ramp and the wall introduce a complicated flow structure which could strongly affect the efficiency of the inlet. Author

A93-21925
FLOW AROUND TWO CIRCULAR CYLINDERS BY THE RANDOM-VORTEX METHOD
A. SLAOUTI and P. K. STANSBY (Manchester Victoria Univ., United Kingdom) Journal of Fluids and Structures (ISSN 0889-9746) vol. 6, no. 6 Nov. 1992 p. 641-670. Research supported by SERC and Department of Energy refs
Copyright
The random-vortex method is used to investigate the flow around two circular cylinders in side-by-side and tandem arrangements. The numerical scheme incorporates the vortex-in-cell method with overlapping meshes and is a combination of various procedures which have developed previously. The commputations are carried out at a Reynolds number of 200 where the near-wake is predominantly two-dimensional and laminar and vortex shedding is known to occur on a single cylinder. The computed flow fields reproduce the various flow regimes observed experimentally at high subcritical Reynolds numbers with the corresponding force and frequency characteristics. The method may handle a general arrangement of circular cylinders. Author

A93-22227
COMPUTATIONS OF A TWIN-JET IMPINGEMENT ON A FLAT SURFACE
SHU-HAO CHUANG (National Chunghsing Univ., Taichung, Taiwan) and MING-HUA CHEN (Chung-Chou Inst. of Technology, Chunghua, Taiwan) Chinese Society of Mechanical Engineers, Journal (ISSN 0257-9731) vol. 13, no. 5 Oct. 1992 p. 391-400. refs
Results are presented of a numerical investigation to determine the flow and pressure patterns of 2D impinging twin lift-jet with upper flat plate. Both unsteady continuity and momentum equations are cast into the suitable finite-difference equations. The calculation procedure employs the two-equation k-epsilon turbulence model, and the solution technique uses the SIMPLE-C algorithm coupled with the power-law scheme. It is shown that the flow pattern is strongly affected by the exit jet height and impingement angle. The phenomenon of fountain up-wash flow between the two lift-jet flow is generated when the impinging twin-jet directs outward or normal to the ground surface. The associated lift loss of aircraft is caused by the fountain up-wash flow and lift-jet flow. The self-similar mean-velocity across the fountain is predicted and satisfactory agreement is found with relevant experimental data. P.D.

A93-22230
NUMERICAL SIMULATION OF UNSTEADY TRANSONIC NOZZLE FLOWS
SHEN-MIN LIANG and CHIEN-KO HO (National Cheng Kung Univ., Tainan, Taiwan) Chinese Society of Mechanical Engineers, Journal (ISSN 0257-9731) vol. 13, no. 5 Oct. 1992 p. 471-477. refs

Time-dependent Euler equations used to simulate unsteady flows in channels are solved with a time-accurate implicit TVD method. The unsteady flows result from the fluctuating back pressure. This solver is constructed in a finite-volume fashion and is based on Yee's (1985) linearized conservative implicit form of TVD schemes, the approximate factorization of Beam and Warming (1978), and a space-varying time step. The method is shown to be efficient and accurate in time and space. In the regime of slowly time-varying pressure fluctuation, the effects of the back pressure fluctuation amplitude and frequency on the shock oscillation are investigated for quasi-1D nozzle flows. It is shown that the shock oscillation frequency is the same as the back pressure fluctuation frequency. The variations in the amplitude and the frequency of the back pressure fluctuation are not found to significantly affect the average shock position. P.D.

A93-22263
PREDICTION OF ROTOR DYNAMIC DESTABILIZING FORCES IN AXIAL FLOW COMPRESSORS
J. COLDING-JORGENSEN (Odegaard & Danneskiold-Samsoe ApS, Copenhagen, Denmark) ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202) vol. 114, no. 4 Dec. 1992 p. 621-625. refs
Copyright

A simple analysis of the perturbed flow in an axial compressor stage with whirling rotor is presented, based on the actuator disk analysis of Horlock and Greitzer (1983), and the gas force on the rotor is calculated on this basis. It appears that in the normal operation range of an axial compressor, the whirl direction is predicted to be forward always. Backward whirl is predicted to take place only at very low flow rates, well below the normally expected stall limit. Experimentally, forces were indeed found in direction of backward whirl for low flow rates, and in direction of forward whirl for high flow rates, in the results reported by Vance and Laudadio (1984), as analyzed by Ehrich (1989). While this experimental evidence supports the present theory qualitatively, a direct comparison of the measured and predicted destabilizing force has yet to be carried out. Author

A93-22264
LOW AREA RATIO AIRCRAFT FUEL JET-PUMP PERFORMANCES WITH AND WITHOUT CAVITATION
M. MARINI, A. MASSARDO, A. SATTA, and M. GERACI (Genoa Univ., Italy) ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202) vol. 114, no. 4 Dec. 1992 p. 626-631. Research supported by MPI refs
(Contract CNR-91,02814,11)
Copyright

The experimental analysis performed on several small size low area ratio aircraft fuel jet pumps in JP4 is outlined. The variables investigated were area ratio, nozzle and throat diameters, nozzle and suction pressures. The experimental values of head ratio were compared to a one-dimensional theoretical prediction method previously found to be applicable to moderate and high area ratio pumps. The results show the necessity of making some modifications in the model at low flow coefficient values. Measured wall static pressures were also compared with the results of an axisymmetric finite difference turbulent calculation; the comparisons are generally in good agreement. The development of cavitation and related parameters were also investigated. In order to enhance cavitation resistance, which is particularly important in the field of aeronautics, some studies were carried out on two stage jet pumps. The results obtained are outlined and discussed. Author

A93-22298#
AN AEROSPACE PLANE AS A DETONATION WAVE RAMJET/AIRFRAME INTEGRATED WAVERIDER
TARAS M. ATAMANCHUK, JEAN P. SISLIAN, and RUDOLPH DUDEBOUT (Toronto Univ., Downsview, Canada) Dec. 1992 10 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 Research supported by Craig Research, Inc refs
(AIAA PAPER 92-5022) Copyright

Shocked-combustion ramjets are investigated as a means of hypersonic propulsion for lifting-propulsive waveriders. An explicit Godunov scheme, employing finite reaction rate combustion of a stoichiometric mixture of hydrogen and air, is used to determine the inviscid flowfield generated by an axisymmetric body. The shock and discontinuity tracking capability of this computational method is used to construct a series of wall contours, at shock wave and wall intersection points, to form a body geometry operating at design conditions. The axisymetric flowfield is then used to generate a three-dimensional waverider containing this flowfield and operating at two values of flight dynamic pressure. The pressure, and hence forces, acting on the surfaces of the waverider are calculated and used to determine various vehicle performance parameters. Author

A93-22303#
SOME ASPECTS OF THE AERODYNAMIC METHODOLOGY IN HYPERSONIC VEHICLE CONCEPT STUDIES
H. HOLLANDERS, G. LAVAL, F. NOEL, J. C. PAULAT (Aerospatiale, Les Mureaux, France), and P. GARNERO (Aerospatiale, Verrieres-le-Buisson, France) Dec. 1992 13 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 Research supported by DRME, ESA, and CNES refs
(AIAA PAPER 92-5027) Copyright

This paper aims to illustrate the impact of CFD along with ground and flight experiments on aerodynamic hypersonic studies. Both validations and reliable applications of the numerical Euler, boundary layer, Navier-Stokes, and Monte Carlo tools are demonstrated. CFD is presented through several realistic applications on typical vehicles including classic and reusable launchers, space planes and planetary entry probes. R.E.P.

A93-22304#
STUDY OF FLOW PHENOMENA IN HIGH SPEED INTAKES
W. W. KOSCHEL, W. RICK, and T. RUEGGEBERG (Aachen, Rheinisch-Westfaelische Technische Hochschule, Germany) Dec. 1992 15 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(Contract DFG-SFB-253)
(AIAA PAPER 92-5029) Copyright

Analytical and numerical studies were conducted to analyze viscous effects in high-speed intakes for airbreathing propulsion systems of the lower stage of a generic TSTO aerospace plane. The flow in the mixed shock compression inlet is analyzed in detail at design and off-design flight conditions. The results of the numerical flow simulation are in good agreement with the pressure measurements and with the phenomena observed by visualization methods. R.E.P.

A93-22305*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
APPLICATION OF SPACE-MARCHING METHODS TO HYPERSONIC FOREBODY FLOW FIELDS
SCOTT L. LAWRENCE (NASA, Ames Research Center, Moffett Field, CA) Dec. 1992 10 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5030) Copyright

The heavy reliance on CFD in the design of hypersonic flight vehicles emphasizes the importance of choosing computationally efficient techniques. As a result, the development and application of space-marching flow solvers for the parabolized Navier-Stokes equations have received considerable attention in the past decade. This paper summarizes a space-marching approach used at NASA Ames Research Center for the analysis of hypersonic vehicle forebodies. Aspects of the simulation process are addressed that contain features unique to space-marching flow solvers, such as

grid generation, initial condition specification, and finite-rate chemistry models. For completeness, sections are also included on turbulence modeling and equilibrium air chemistry modeling. The discussion includes an overview of the computational methods utilized as well as a number of relevant results. Author

A93-22319*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CFD COMPARISONS WITH WIND TUNNEL AND FLIGHT DATA FOR THE X-15
RICHARD W. HAWKINS and ARTHUR D. DILLEY (Analytical Services and Materials, Inc., Hampton, VA) Dec. 1992 12 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(Contract NAS1-19320)
(AIAA PAPER 92-5047) Copyright

The wind tunnel and flight data from the X-15 program have been evaluated for utilization in CFD calibration research. From the analysis, experimental data suitable for CFD code calibration are identified. R.E.P.

A93-22320*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
THE BURNETT SHOCK STRUCTURES IN LOW DENSITY HYPERSONIC FLOWS
GOANG-SHIN LIAW, ZHENG-TAO DENG (Alabama A & M Univ., Huntsville), LYNN C. CHOU (NASA, Marshall Space Flight Center, Huntsville, AL), and JIA-DA MO (Memphis State Univ., TN) Dec. 1992 7 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(Contract F33657-90-C-2269)
(AIAA PAPER 92-5048) Copyright

One-dimensional shock structures in low density hypersonic flows have been studied numerically by solving the Burnett and Navier-Stokes equations. A new lower-upper scheme has been developed to obtain the steady and stationary normal shock solutions by the time-marching technique. The new scheme directly employs the implicit finite difference method without computing the eigenvalues, and it is first-order accurate in time and second-order accurate in space. The computed shock structures have been compared with available experimental data, and they are in good agreements. Numerical results show that the Burnett calculations has less numerical diffusion than the Navier-Stokes calculations does. As to the shock thickness, the Burnett solutions are apparently superior than the Navier-Stokes solutions. Author

A93-22321*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INSTABILITY AND TRANSITION IN THREE-DIMENSIONAL SUPERSONIC BOUNDARY LAYERS
M. R. MALIK and P. BALAKUMAR (High Technology Corp., Hampton, VA) Dec. 1992 18 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(Contract NAS1-19299)
(AIAA PAPER 92-5049) Copyright

Linear stability of three-dimensional flow past a 5 deg semi-vertex sharp cone at 2 deg incidence in Mach 3.5 free-stream is studied. Computed laminar mean flow profiles along the leeward line of symmetry are highly inflectional and, hence, much more unstable than the profiles along the windward line of symmetry. Accordingly, transition occurs much earlier along the leeward line both in the present calculations (based upon eN approach) and in the experiments of King (1991) performed in NASA Langley 'quiet' tunnel. Boundary-layer transition in the region between the two symmetry lines is influenced by the crossflow generated due to the angle of attack and, as a consequence, it progressively moves upstream with increasing azimuthal angle measured from the windward line. The computed transition front is qualitatively similar to the experimental results, although some differences remain. Author

A93-22322# National Aeronautics and Space Administration, Washington, DC.
A STUDY OF HYPERSONIC SWEPT SHOCK WAVE/TURBULENT BOUNDARY LAYER INTERACTIONS USING A CONICAL NAVIER-STOKES CODE
PATRICK E. RODI and DAVID S. DOLLING (Texas Univ., Austin) Dec. 1992 17 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 Research supported by NASA, USAF, U.S. Navy, et al. refs
(Contract NGT-50172)
(AIAA PAPER 92-5050) Copyright

A computational study has been performed of sharp fin-induced swept shock wave/turbulent boundary layer interactions at low hypersonic Mach numbers. The objective was to determine if results obtained using a conical Navier-Stokes code, particularly the peak heating and pressure, are adequate for engineering predictions. The advantage of the conical approach is that the problem becomes two-dimensional and requires much less computational effort than a fully three-dimensional calculation. In this code, the standard Baldwin-Lomax model is used for turbulent closure and its performance is studied in some detail. To assess the approach interactive flowfields generated by unswept sharp fins at two angles of attack at each of three hyprsonic freestream Mach numbers (5, 6, 11) have been calculated and the results compared with experimental wall pressure and heat transfer data. Although the conical Navier-Stokes/Baldwin-Lomax approach is reasonably successful at Mach numbers up to 5, the performance deteriorates as the Mach number is increased. Nevertheless, the approach could be a valuable tool in preliminary parametric design studies. Author

A93-22335#
VALIDATION OF AERODYNAMIC SIMULATION METHODS FOR HERMES SPACEPLANE AND FUTURE HYPERSONIC VEHICLES
MICHEL MALLET, JACQUES PERIAUX, PHILIPPE ROSTAND, and BRUNO STOUFFLET (Dassault Aviation, Saint-Cloud, France) Dec. 1992 17 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5065) Copyright

Some examples of macro or micro aerodynamic problems for the Hermes design including the positioning of airbrakes, the simulation of the flow between the elevon and the deflected rudder, and the local flow over the canopy are described. These examples are analyzed utilizing 3D Euler and Navier-Stokes codes with real gas assumption in an industrial environment. A case of scientific validation of hypersonic codes that was performed in a workshop on reentry problems is presented. R.E.P.

A93-22361#
STARTING AND TEST RHOMBUS CHARACTERISTICS OF TWO-DIMENSIONAL SUPERSONIC FREE-JET NOZZLE/GENERIC SUPERSONIC AIRCRAFT INLET CONFIGURATIONS
D. W. PRUITT and L. B. BATES (Sverdrup Technology, Inc., Arnold AFB, TN) Dec. 1992 15 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5091)

An experimental program to determine the starting and test rhombus characteristics of two-dimensional supersonic free-jet nozzle/generic supersonic inlet configurations was conducted at Mach numbers of 1.7, 2.5, and 3.3. The inlet had swept side walls, so the free-jet nozzle exit incorporated an oblique nozzle extension to extend the test rhombus. The inlet was positioned either to capture or bypass the free-jet nozzle upper surface boundary layer. The starting characteristics of the configurations were experimentally investigated as a function of (1) the relative physical size of the inlet capture area and the free-jet nozzle exit area, and (2) the inlet mass flow capability. The test rhombus capacity was investigated as a function of the proximity of the free-jet nozzle exit walls to the inlet leading edges. Author

A93-22371*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HYPERSONIC TURBULENT EXPANSION-CORNER FLOW WITH SHOCK IMPINGEMENT
KUNG-MING CHUNG and FRANK K. LU (Texas Univ., Arlington) Dec. 1992 10 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(Contract NAG1-891)
(AIAA PAPER 92-5101) Copyright

Mean and fluctuating surface pressure data were obtained in a Mach 8, turbulent, cold flow past an expansion corner subjected to shock impingement. The expansion corner of 2.5 or 4.25 deg was located at 0.77 m (30.25 in.) from the leading edge of a shape-edged flat plate while an external shock, generated by either a 2- or 4-deg sharp wedge, impinged at the corner, or at one boundary layer thickness ahead or behind the corner. The mean pressure distribution was strongly influenced by the mutual interaction between the shock and the expansion. For example, the upstream influence decreased when the shock impinged downstream of the corner. Also, the unsteadiness of the interactions was characterized by an intermittent region and a local rms pressure peak near the upstream influence line. The peak rms pressure fluctuations increased with a larger overall interaction strength. Shock impingement downstream of the corner resulted in lower peaks and also in a shorter region of reduced fluctuation levels. These features may be exploited in inlet design by impinging the cowl shock downstream of an expansion corner instead of at the corner. In addition, a limited Pitot pressure survey showed a thinning of the boundary layer downstream of the corner. Author

A93-22373#
EXPERIMENTAL RESULTS OF SHOCK TRAINS IN RECTANGULAR DUCTS
G. A. SULLINS (Johns Hopkins Univ., Laurel, MD) and G. H. MCLAFFERTY (McLafferty Consulting, Inc., North Palm Beach, FL) Dec. 1992 21 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5103) Copyright

A facility was built to investigate shock trains in a rectangular duct. A throttle valve, installed downstream of the diffuser, was used to create a back pressure and hence a shock train, thus simulating the process that occurs in a ramjet engine. Results are presented for shock trains in a duct with a rectangular cross section. The shock train length is correlated to the conditions at the start of the shock train and the pressure rise achieved through the shock system. Two different step heights were used to determine the effect that the scramjet injectors will have on the ramjet isolator performance. Instream pitot and cone static pressure surveys were made downstream of the shock train. Author

A93-22374#
TECHNIQUES FOR THE MEASUREMENT OF SCRAMJET INLET PERFORMANCE AT HYPERSONIC SPEEDS
D. M. VAN WIE (Johns Hopkins Univ., Laurel, MD) Dec. 1992 16 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5104) Copyright

Various techniques for the measurement of hypersonic inlet performance are described, and required measurement accuracies are estimated using sample engine cycle calculations and a simplistic mission analysis. The accuracy of each performance technique is estimated using several levels of typical measurement uncertainties, and recommendations for preferred measurement techniques are provided. The analysis indicates that the required performance measurement accuracies can be met using several different techniques for tests at Mach 5 conditions. As the freestream Mach number increases, the measurement challenges become much more difficult. At Mach 20 conditions, it will be very difficult to achieve the required performance measurement accuracies without further improvements in test techniques. Author

A93-22443
STABILITY OF THE VERTICAL AUTOROTATION OF A SINGLE-WINGED SAMARA
D. SETER and A. ROSEN (Technion - Israel Inst. of Technology, Haifa) ASME, Transactions, Journal of Applied Mechanics (ISSN 0021-8936) vol. 59, no. 4 Dec. 1992 p. 1000-1008. refs
Copyright

A numerical model to investigate the stability of the vertical autorotation of a single-winged samara is presented. This model is obtained after the method of small perturbations about an equilibrium state is applied on the nonlinear equations of motion of the samara. The aerodynamic stability derivatives of the wing are obtained by numerical differentiation. The model is used in order to study the influence of different parameters on the stability. Since the stability is highly dependent on the basic equilibrium state, the influence of the different parameters on the basic state is also presented and discussed. The theoretical model is validated by comparing its results with qualitative experimental results. Author

A93-22552*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN ALGEBRAIC TURBULENCE MODEL FOR THREE-DIMENSIONAL VISCOUS FLOWS
R. V. CHIMA (NASA, Lewis Research Center, Cleveland, OH), P. W. GIEL (Sverdrup Technology, Inc., Brook Park, OH), and R. J. BOYLE (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-14102 refs
(AIAA PAPER 93-0083) Copyright

An algebraic turbulence model is proposed for use with three-dimensional Navier-Stokes analyses. It incorporates features of both the Baldwin-Lomax and Cebeci-Smith models. The Baldwin-Lomax model uses the maximum of a function f(v) to determine length and velocity scales. An analysis of the Baldwin-Lomax model shows that f(v) can have a spurious maximum close to the wall, causing numerical problems and non-physical results. The proposed model uses integral relations to determine delta(*) u(sub e) and delta used in the Cebeci-Smith mode. It eliminates a constant in the Baldwin-Lomax model and determines the two remaining constants by comparison to the Cebeci-Smith formulation. Pressure gradient effects, a new wake model, and the implementation of these features in a three-dimensional Navier-Stokes code are also described. Results are shown for a flat plate boundary layer, an annular turbine cascade, and endwall heat transfer in a linear turbine cascade. The heat transfer results agree well with experimental data which shows large variations in endwall Stanton number contours with Reynolds number. Author

A93-22580#
INLET VELOCITY PROFILE EFFECTS ON TURBULENT SWIRLING FLOW PREDICTIONS
MINGCHUN DONG and DAVID G. LILLEY (Oklahoma State Univ., Stillwater) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0133) Copyright

The validity of flowfield predictions resulting from the choice of inlet velocity profile is assessed. Results demonstrate that realistic predictions are forthcoming only from the inclusion of realistic axial, radial and swirl velocity profile as inlet conditions. The ensuing flowfields are characterized via velocity profiles and streamline patterns, and illustrate the large-seale effects of inlet swirl and velocity profiles on flowfields. Clearly, measured inlet profiles must be used in future turbulence modeling development studies for improved simulations of flowfields. Author

A93-22591*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PREDICTION OF ACTIVE CONTROL OF SUBSONIC CENTRIFUGAL COMPRESSOR ROTATING STALL
PATRICK B. LAWLESS and SANFORD FLEETER (Purdue Univ.,

West Lafayette, IN) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by U.S. Army and NASA refs
(AIAA PAPER 93-0153) Copyright

A mathematical model is developed to predict the suppression of rotating stall in a centrifugal compressor with a vaned diffuser. This model is based on the employment of a control vortical waveform generated upstream of the impeller inlet to damp weak potential disturbances that are the early stages of rotating stall. The control system is analyzed by matching the perturbation pressure in the compressor inlet and exit flow fields with a model for the unsteady behavior of the compressor. The model was effective at predicting the stalling behavior of the Purdue Low Speed Centrifugal Compressor for two distinctly different stall patterns. Predictions made for the effect of a controlled inlet vorticity wave on the stability of the compressor show that for minimum control wave magnitudes, on the order of the total inlet disturbance magnitude, significant damping of the instability can be achieved. For control waves of sufficient amplitude, the control phase angle appears to be the most important factor in maintaining a stable condition in the compressor. Author

A93-22592#
SOLUTION SCHEMES FOR STAGE-BY-STAGE DYNAMIC COMPRESSION SYSTEM MODELING
J. W. LINDAU and WALTER F. O'BRIEN (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0154) Copyright

Stage-by-stage dynamic compression system models are based on solving the Euler equations with additional source terms. A comparison of the performance of several discretization techniques is made. The results of a simulated compressor surge show that flux difference splitting modified to include source items is the best technique of discretization in the dynamic compression system model. R.E.P.

A93-22594#
FORCING FUNCTION GENERATOR FLUID DYNAMIC EFFECTS ON COMPRESSOR BLADE GUST RESPONSE
KUK H. KIM and SANFORD FLEETER (Purdue Univ., West Lafayette, IN) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract F49620-88-C-0022)
(AIAA PAPER 93-0157) Copyright

To investigate the fundamental flow forcing function phenomena generating different blade row gust responses, in particular attached and separated flow forcing functions, a series of experiments are performed in an extensively instrumented axial flow research compressor. In these experiments, the gust ratio magnitude is controlled without affecting the forcing function fluid dynamics, i.e., attached or separated flow, thereby enabling a controlled study of the effect of steady loading. Periodic 2-E unsteady aerodynamic forcing functions to the first stage rotor are generated by fundamentally equivalent honeycomb sections and flat plate airfoils, with unsteady linear theory gust requirements considered. Then the resulting rotor blade row gust response is measured over a range of steady loading levels and the gust response data correlated with the appropriate linear theory predictions. These experiments show that the forcing function generator fluid dynamics is significant with regard to the resulting unsteady aerodynamic gust response. Also demonstrated is the decreased correlation of the gust response data with linear theory predictions as the steady loading is increased. Author

A93-22601*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CFD ZONAL MODELING OF LEADING-EDGE ICE EFFECTS FOR A COMPLETE AIRCRAFT
J. M. SUMMA, D. J. STRASH, and D. A. LEDNICER (Analytical Methods, Inc., Redmond, WA) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS3-26310)
(AIAA PAPER 93-0167) Copyright

A simplified, uncoupled zonal procedure was utilized to assess the capability of numerically simulating icing effects on a Boeing 727-200 aircraft. The computational approach combines potential flow, plus boundary layer simulations by VSAERO for the un-iced aircraft forces and moments, with Navier-Stokes simulations by ARC3D for the incremental forces and moments due to iced components. These are compared with wind tunnel longitudinal force and moment data. Although the computational results compared favorably with the test data in the linear angle of attack range, it is clear that for general aircraft icing calculations, a multiblock Navier-Stokes code will be required for the viscous component of this zonal method. Author

A93-22602*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRACKING OF RAINDROPS IN FLOW OVER AN AIRFOIL
JAMES R. VALENTINE and RAND DECKER (Utah Univ., Salt Lake City) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG1-1232)
(AIAA PAPER 93-0168) Copyright

The splashback that occurs when raindrops impact an airfoil results in an 'ejecta fog' of small droplets around the leading edge. Acceleration of these droplets by the air flow field is a momentum sink for the air flow and has been hypothesized to contribute to the degradation of airfoil performance in heavy rain. Presented here is a one-way coupled Eulerian-Lagrangian particle tracking scheme to evaluate droplet number densities and momentum sink terms around a NACA 64-210 airfoil section for three rainfall rates. A laminar air flow field is determined with a standard CFD code and input to the particle tracking algorithm. Raindrops are assumed to be non-interacting, non-deforming, non-evaporating, and non-spinning spheres and are tracked through the curvilinear grid used by the air flow code. A simple model is used to simulate impacts and the resulting splashback on the airfoil surface. Author

A93-22603#
IMPROVEMENT OF THE ONERA 3D ICING CODE, COMPARISON WITH 3D EXPERIMENTAL SHAPES
T. HEDDE and D. GUFFOND (ONERA, Chatillon, France) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0169) Copyright

A 3D icing model has been developed at ONERA; it is shortly described here, emphasizing the new aspects of it: Euler inviscid flow calculation, droplet trajectories in a 3D grid, leading edge remeshing. The calculated 3D ice shapes are compared to experimental ones obtained on a non-rotating rotor blade tip; the agreement is good. Then, the numerical results are compared to experimental shapes exhibiting scallop (or lobster tail) effects. The calculated shapes are quite underestimated. The scallop effect is explained through shadow and heat transfer gradient mechanisms. A qualitative ballistic model enables us to simulate the grow of 2D scalloped ice shapes. Author

A93-22610#
3-D LDV MEASUREMENTS OVER A DELTA WING IN PITCH-UP MOTION
N. T. HOANG, O. K. REDINIOTIS, and D. P. TELIONIS (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0185) Copyright

A detailed investigation of the velocity and vorticity fields over a 75 deg-sweep delta wing undergoing a ramp-like pitch-up motion is carried out through three-component LDV measurements. The evolution of the flow field in four planes normal to the free-stream is captured at 100 time instants through the wing motion. The delta wing is pitched through angles of attack ranging from 28

deg to 68 deg. From the velocity data at each incidence, the corresponding vorticity field is calculated. Hysteresis effects on vortex development and breakdown, with respect to the steady case, are studied through axial velocity and vorticity contours. The topology of streamlines and vortex lines are compared with the corresponding topologies of the steady case. It is found that vortex breakdown can be detected first by a drastic reduction of the axial velocity. In fact, this effect is developing asymmetrically, beginning in the inboard side of the vortex. This is followed by a reduction of the axial vorticity component and finally by a complete reversal of the circumferential vorticity component. Some effects of parameters like Reynolds number, model thickness, nondimensional pitch-up rate, free-stream turbulence on the developing flow field are addressed. Author

A93-22611#
NUMERICAL SIMULATION OF DYNAMIC LIFT ENHANCEMENT USING OSCILLATORY LEADING EDGE FLAPS
WEI W. TSENG (U.S. Navy, Naval Air Warfare Center, Warminster, PA), FU L. TSUNG, and LAKSHMI N. SANKAR (Georgia Inst. of Technology, Atlanta) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0186)
The utilization of some concepts in practical aircraft technology requires an understanding of physical phenomena occurring during vortex shedding processes caused by forced oscillation. The performance of sufficient wind tests to define these phenomena is expensive. The use of computational fluid dynamic (CFD) methods along with wind tunnel results may reduce test costs. A time dependent Reynolds averaged Navier-Stokes solver has been modified to handle leading and trailing edge control surface motions and the computation of dominant vortex shedding processes during high angles of attack. The method has been validated by complete aircraft configuration studies and computing the effects of trailing edge flap oscillation in an F-5 wing case, F-18 wing alone case and a high aspect ratio wing case. Computational results were compared with F-5 trailing edge oscillation wind tunnel data. A.O.

A93-22613#
AERODYNAMIC FOUNDATIONS FOR USE OF UNSTEADY AERODYNAMIC EFFECTS IN FLIGHT CONTROL
THOMAS E. MCLAUGHLIN, MICHAEL C. ROBINSON, and MARVIN W. LUTTGES (Colorado Univ., Boulder) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0188)
Unsteady aerodynamic effects have long been postulated as a means to enhance low speed performance of aircraft. Before the phenomenon can be exploited, the temporal nature of these forces must be quantified and predicted over the widest possible range of forcing conditions. To this end, unsteady aerodynamic force generation collected from numerous experimental efforts was examined over a wide range of non-dimensional pitch rates, Reynolds numbers, Mach numbers, motion histories and two- and three-dimensional airfoils. Unsteady aerodynamic forces were found to change linearly with non-dimensional time. The duration of the unsteady event was found to be a reliable function only of non-dimensional pitch rate or frequency, and of the initial state of the airfoil. Force magnitudes generated at any given time in the event were found to depend simply on the same parameters and on airfoil static characteristics. In all cases, the unsteady forces produced were found highly predictable and well-correlated across the range of forcing parameters. Author

A93-22614#
A THREE-DIMENSIONAL INVISCID FLOW SOLVER IN CHIMERA FLOW SIMULATION
YONG WANG (California Univ., Davis) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract F33615-90-C-3004)
(AIAA PAPER 93-0190) Copyright
A simple and robust algorithm for steady inviscid flow, in terms of primitive variables, is described for body fitted coordinates. This algorithm has been adapted for the Chimera framework for the calculation of complex geometric problems. This method is intended to be used for preliminary engineering analysis, and as a means of generating good initial solutions for Navier-Stokes solvers. Solutions for the flow about a sphere has been obtained for both single and overset grids. The results, ranging from incompressible, M-infinity = 0.2, to critical flow, M-infinity = 0.55, show good agreement with the exact potential flow solution. The flow about an ellipsoid has also been obtained and a comparison to an implicit Euler scheme has been made. Author

A93-22615*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TURBULENCE MODEL EVALUATION FOR THE PREDICTION OF FLOWS OVER A SUPERCRITICAL AIRFOIL WITH DEFLECTED AILERON AT HIGH REYNOLDS NUMBER
W. K. LONDENBERG (Vigyan, Inc., Hampton, VA) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS1-18585)
(AIAA PAPER 93-0191) Copyright
Navier-Stokes solutions about a supercritical airfoil with aileron deflection have been computed using the CFL3D code coupled with the Baldwin-Lomax, Johnson-King, Baldwin-Barth, and Spalart-Allmaras turbulence models. Computations were made at a Mach number of 0.716 and chord Reynolds numbers of 5, 15, and 25 million. The airfoil was analyzed with both 0 deg and 2 deg (TED) aileron deflections. Comparisons over a range of angles-of-attack showed that solutions obtained using the Baldwin-Barth turbulence model presented the best agreement with experimental pressures and sectional lift coefficients. However, Reynolds number trends in sectional lift coefficient and in aileron effectiveness were not predicted consistently. Author

A93-22616*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
GRID AND DESIGN VARIABLES SENSITIVITY ANALYSES FOR NACA FOUR-DIGIT WING-SECTIONS
IDEEN SADREHAGHIGHI (Old Dominion Univ., Norfolk, VA), ROBERT E. SMITH (NASA, Langley Research Center, Hampton, VA), and SURENDRA N. TIWARI (Old Dominion Univ., Norfolk, VA) Jan. 1993 25 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NCC1-68)
(AIAA PAPER 93-0195) Copyright
Two distinct parameterization procedures are developed for investigating the grid sensitivity with respect to design parameters of a wing-section example. The first procedure is based on traditional (physical) relations defining NACA four-digit wing-sections. The second is advocating a novel (geometrical) parameterization using spline functions such as NURBS (Non-Uniform Rational B-Splines) for defining the wing-section geometry. An interactive algebraic grid generation technique, known as Hermite Cubic Interpolation, is employed to generate C-type grids around wing-sections. The grid sensitivity of the domain with respect to design and grid parameters has been obtained by direct differentiation of the grid equations. A hybrid approach is proposed for more geometrically complex configurations. A comparison of the sensitivity coefficients with those obtained using a finite-difference approach has been made to verify the feasibility of the approach. The aerodynamic sensitivity coefficients are obtained using the compressible two-dimensional thin-layer Navier-Stokes equations. Author

A93-22617*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TRACKING FLOW FEATURES USING OVERSET GRIDS
KALPANA CHAWLA (MCAT Inst.; NASA, Ames Research Center, Moffett Field, CA) and DAVID W. BANKS (California Univ., Davis)

Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0197) Copyright

A method is proposed to use overset grid topology to track dynamic flow features. Features of interest such as moving shock waves and vortices are overset with relatively fine tracker grids. Solutions are computed on the various grids and information is exchanged at intergrid boundaries. A grid track-sensor variable such as pressure is used to track the position of the flow feature to be resolved. The tracker grid is moved to the position where the track-sensor variable has the desired value (generally a maximum or a minimum) and new interpolation coefficients are computed for information exchange across grid boundaries. Solutions are computed at the current location and time-step, and grid motion is brought into the solution via time metrics. The method is demonstrated by tracking a moving shock and vortices shed behind a circular cylinder. It is conjectured that the method would show significant benefits in resolving features such as wakes behind oscillating airfoils and trajectories of jets issuing from rotating nozzles as encountered during thrust-vectoring. Author

A93-22618#
DIRECT NUMERICAL SIMULATION OF TURBULENT FLOW IN A SQUARE DUCT
A. HUSER and S. BIRINGEN (Colorado Univ., Boulder) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Fulbright Foundation, Norwegian Space Agency, and NTNF refs
(Contract N00014-91-J-1086)
(AIAA PAPER 93-0198) Copyright

A direct numerical simulation of a fully developed, low-Reynolds number turbulent flow in a square duct is presented. The numerical scheme employs a time-splitting method to integrate the three-dimensional, incompressible Navier-Stokes equations using spectral/high-order finite difference discretization on a staggered mesh; the nonlinear terms are represented by fifth-order upwind-biased finite differences. The unsteady flow field was simulated at a Reynolds number of 600 based on the mean friction velocity and the duct width, using 96 x 101 x 101 grid points. Turbulence statistics from the fully developed turbulent field are compared with existing experimental and numerical square duct data providing good qualitative agreement. Results from the present study furnishes the details of the corner-effects and near-wall effects in this complex turbulent flow field; also included is a detailed description of the terms in the Reynolds-averaged streamwise momentum and vorticity equations. Author

A93-22619#
NUMERICAL SIMULATION OF THE TURBULENT FLOW IN ROUND JETS
J. J. LIENAU and W. KOLLMANN (California Univ., Davis) Jan. 1993 18 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract F49620-92-J-0418)
(AIAA PAPER 93-0199) Copyright

The turbulent flow in round jets is simulated numerically. A finite difference method is developed using compact differencing in the spatial directions with formally sixth order accuracy and the second order accurate Adams-Bashforth scheme for the time integration. The spatially developing flow in a round jet is computed starting with the inviscid solution and structural and statistical properties of the flow are established. The Kelvin-Helmholtz instability is induced with small disturbances at the jet pipe exit. The vortex sheet rolls up into rings that interact and produce a variety of structures. This flow development is documented in detail and an analysis based on statistical and dynamical properties is presented. Author

A93-22620*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TURBULENCE MODELING FOR COMPLEX HYPERSONIC FLOWS
P. G. HUANG (Eloret Inst., Sunnyvale, CA) and T. J. COAKLEY (NASA, Ames Research Center, Moffett Field, CA) Jan. 1993 7 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0200) Copyright

The paper presents results of calculations for a range of 2D turbulent hypersonic flows using two-equation models. The baseline models and the model corrections required for good hypersonic-flow predictions will be illustrated. Three experimental data sets were chosen for comparison. They are: (1) the hypersonic flare flows of Kussoy and Horstman, (2) a 2D hypersonic compression corner flow of Coleman and Stollery, and (3) the ogive-cylinder impinging shock-expansion flows of Kussoy and Horstman. Comparisons with the experimental data have shown that baseline models under-predict the extent of flow separation but over-predict the heat transfer rate near flow reattachment. Modifications to the models are described which remove the above-mentioned deficiencies. Although we have restricted the discussion only to the selected baseline models in this paper, the modifications proposed are universal and can in principle be transferred to any existing two-equation model formulation. Author

A93-22624*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE EFFECT OF REYNOLDS NUMBER AND TURBULENCE ON AIRFOIL AERODYNAMICS AT -90 DEGREES INCIDENCE
PAUL M. STREMEL (NASA, Ames Research Center, Moffett Field, CA) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0206) Copyright

A method has been developed for calculating the viscous flow about airfoils in with and without deflected flaps at -90 deg incidence. This method provides for the solution of the unsteady incompressible Navier-Stokes equations by means of an implicit technique. The solution is calculated on a body-fitted computational mesh using a staggered grid method. The vorticity is defined at the node points, and the velocity components are defined at the mesh-cell sides. The staggered-grid orientation provides for accurate representation of vorticity at the node points and the continuity equation at the mesh-cell centers. The method provides for the direct solution of the flow field and satisfies the continuity equation to machine zero at each time-step. The method is evaluated in terms of its ability to predict two-dimensional flow about an airfoil at -90 degrees incidence for varying Reynolds number and different boundary layer models. A laminar and a turbulent boundary layer models. A laminar and a turbulent boundary layer model are considered in the evaluation of the method. The variation of the average loading and surface pressure distribution due to flap deflection, Reynolds number, and laminar or turbulent flow are presented and compared with experimental results. The comparisons indicate that the calculated drag and drag reduction caused by flap deflection and the calculated average surface pressure are in excellent agreement with the measured results at a similar Reynolds number. Author

A93-22625*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE COMPUTATION OF THE POST-STALL BEHAVIOR OF A CIRCULATION CONTROLLED AIRFOIL
SAMUEL W. LINTON (Stanford Univ., CA) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NCA2-259)
(AIAA PAPER 93-0207) Copyright

The physics of the circulation controlled airfoil is complex and poorly understood, particularly with regards to jet stall, which is the eventual breakdown of lift augmentation by the jet at some sufficiently high blowing rate. The present paper describes the numerical simulation of stalled and unstalled flows over a two-dimensional circulation controlled airfoil using a fully implicit Navier-Stokes code, and the comparison with experimental results. Mach numbers of 0.3 and 0.5 and jet total to freestream pressure ratios of 1.4 and 1.8 are investigated. The Baldwin-Lomax and

k-epsilon turbulence models are used, each modified to include the effect of strong streamline curvature. The numerical solutions of the post-stall circulation controlled airfoil show a highly regular unsteady periodic flowfield. This is the result of an alternation between adverse pressure gradient and shock induced separation of the boundary layer on the airfoil trailing edge. Author

A93-22626*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DEVELOPMENT OF AN ENGINEERING LEVEL PREDICTION METHOD FOR HIGH ANGLE OF ATTACK AERODYNAMICS
PATRICK H. REISENTHEL, LAURA C. RODMAN (Nielsen Engineering & Research, Inc., Mountain View, CA), and DAVID NIXON (Belfast, Queen's Univ., United Kingdom) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS1-19529)
(AIAA PAPER 93-0208) Copyright
The present work is concerned with predicting the unsteady flow considered to be the cause of the structural failure of twin vertical tail aircraft. An engineering tool has been produced for high angle of attack aerodynamics using the simplest physical models. The main innovation behind this work is its emphasis on the modeling of two key aspects of the dominant physics associated with high angle-of-attack airflows, namely unsteady separation and vortex breakdown. Author

A93-22627#
UNSTEADY LAMINAR SEPARATION ON LOW-REYNOLDS-NUMBER AIRFOILS
J. C. M. LIN and LAURA L. PAULEY (Pennsylvania State Univ., University Park) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract N00014-90-J-1169)
(AIAA PAPER 93-0209) Copyright
The detailed unsteady separation structure of a low-Reynolds-number Eppler 387 airfoil was numerically studied using a time accurate artificial compressibility code. Periodic vortex shedding from the separation was observed in all cases studied. The boundary layer developed into a structure which was reminiscent of a free shear flow, where vortex roll-up and pairing were the dominant features. Although the small-scale turbulence was not modeled in this study, the time-averaged results of global parameter and local parameters compared well with the experimental data of McGhee, Walker & Millard (1988). The time-averaged results exhibited many features of a transitional bubble, namely the nearly stagnant recirculating fluid downstream of the separation point and an abrupt increase of the surface pressure in the reattachment region. This suggests that the unsteady large-scale structure controls the separation on low-Reynolds-number airfoils and small-scale turbulence only plays a secondary role. Author

A93-22628*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
INTERFEROMETRIC INVESTIGATIONS OF COMPRESSIBLE DYNAMIC STALL OVER A TRANSIENTLY PITCHING AIRFOIL
M. S. CHANDRASEKHARA (U.S. Navy-NASA Joint Inst. of Aeronautics; U.S. Naval Postgraduate School, Monterey, CA), L. W. CARR (U.S. Army; NASA, Ames Research Center, Moffett Field, CA), and M. C. WILDER (U.S. Navy-NASA Joint Inst. of Aeronautics, Monterey; MCAT Inst., San Jose, CA) Jan. 1993 18 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by USAF refs
(AIAA PAPER 93-0211)
A nonintrusive study of the compressibility effects on dynamic stall of a transiently pitching airfoil is performed. It is found that dynamic stall occurs quickly as the separation bubble bursts. Compressibility lowers the angle of attack at which stall occurs, principally due to unfavorable interaction with the airfoil boundary layer. R.E.P.

A93-22630#
THE THREE-DIMENSIONAL SEPARATED FLOW STRUCTURE IN A VARIABLE ASPECT RATIO SUDDEN EXPANSION DUCT
G. PAPADOPOULOS, M. V. OTUGEN, and G. C. VRADIS (Polytechnic Univ., Brooklyn, NY) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0213) Copyright
The incompressible turbulent flow over a backward-facing step in a rectangular duct was investigated. The Reynolds number, based on the step height and oncoming freestream velocity, was 26,200 and aspect ratios ranging from 1 to 28 were investigated. Results include wall static pressure contours on both step and flat walls, and surface flow visualization on step, side and flat walls. Mean values of the pressure coefficient downstream of reattachment are observed to decrease with smaller aspect ratios and fluctuating pressure levels near flow reattachment increase to a maximum at an aspect ratio of 4, but decrease for small aspect ratios. A pair of counter rotating eddies, normal to the step wall, are observed immediately downstream of the step and near the side walls. Between these eddies there are secondary eddies induced, the number of which depends on the aspect ratio. Furthermore, flat wall visualizations reveal a three-dimensional separation bubble downstream of the step. The spanwise extent and streamwise location of this bubble significantly depend on aspect ratio, and a critical aspect ratio exists below which no bubble appears. Author

A93-22632#
TOTAL-PRESSURE LOSS IN SUPERSONIC PARALLEL MIXING
DIMITRI PAPAMOSCHOU (California Univ., Irvine) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0216) Copyright
A quasi-one-dimensional model for the planar, confined shear layer is constructed with the purpose of obtaining estimates of total-pressure loss and static-pressure variation due to turbulent mixing. The turbulent Prandtl and Lewis numbers are assumed to be unity. It is found that entropy production is strongly coupled to the intrinsic compressibility, with total-pressure losses becoming significant as the convective Mach number increases. For the isothermal case, the entropy flux is roughly proportional to the third power of the velocity difference, and the equivalent total pressure ratio decays exponentially with the square of the convective Mach number. Pressure gradients in a parallel channel are strong and adverse at high compressibility levels. The model predictions of equivalent total-pressure ratio and shear-layer displacement thickness compare well with existing experimental data. Author

A93-22633#
EXPERIMENTAL STUDIES OF THE TURBULENT STRUCTURE OF SUPERSONIC MIXING LAYERS
J. P. BONNET, J. R. DEBISSCHOP, and O. CHAMBRES (Poitiers Univ., France) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract DRET-90-068)
(AIAA PAPER 93-0217) Copyright
Two supersonic mixing layers are experimentally analyzed for convective Mach numbers of 0.525 and 0.64. Planar visualizations and associated high order moments of velocity fluctuations by laser Doppler velocimetry and hot-wire rakes measurements are presented and discussed. In the longitudinal plane, the higher convective Mach number flow exhibits less large scale structures, both from visualizations and from hot-wire rakes. No convective Mach number effect is observed on the high order statistics obtained from LDV. From the spanwise visualizations, the three-dimensional character of the flow is quite evident at the higher convective Mach number. A striking evidence is that the spanwise scales are nearly constant in the streamwise direction for $Mc = 0.64$ and the corresponding wavelengths are not scaled on the local vorticity thickness in the fully developed region. Quite

different behavior are observed at the lower convective Mach number. Author

A93-22687#
PREDICTION OF FLUCTUATING PRESSURE IN ATTACHED AND SEPARATED COMPRESSIBLE FLOW
A. L. LAGANELLI (Science Applications International Corp., Fort Washington, PA), H. W. WOLFE, and K. WENTZ (USAF, Wright Lab., Wright-Patterson AFB, OH) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract F33615-87-C-3227)
(AIAA PAPER 93-0286) Copyright
A methodology is presented that estimates peak rms pressure in the intermittent region of 2D/3D shock-boundary layer interactions. In order to obtain these estimates, deterministic parameters were used to assist in the design process. For this situation, approach flow conditions were used together with a new inviscid shock angle for the oblique shock inviscid pressure equation to correlate the data. The technique, which was developed from a limited database (M less than or equal to 5), provides for the prediction of acoustic loads associated with compression ramps and fin-generated interactions. Recommendations are made to estimate interactions developed from shock impingement of leading edge surfaces and corner flows where no acoustic database exists. Author

A93-22689#
EXPERIMENTAL AND NUMERICAL INVESTIGATION OF MACH 2.5 SUPERSONIC MIXED COMPRESSION INLET
AKIRA FUJIMOTO (Kawasaki Heavy Industries, Ltd., Kakamigahara, Japan) and NOBUO NIWA (Kawasaki Heavy Industries, Ltd., Jet Engine Div., Kobe, Japan) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Society of Japanese Aerospace Companies and Kawasaki Heavy Industries, Ltd refs
(AIAA PAPER 93-0289) Copyright
A two-dimensional supersonic mixed-compression inlet of Mach 2.5 was investigated experimentally and numerically. A full automatic model control and data acquisition system was developed for the experiment. The inlet start data and the performance data were obtained. Then the flow visualization data were compared with the results of our previous two-dimensional calculations. The experimental results supported our 'further-pressure-recovery-improvement-flow model' in the critical condition, which was suggested in our previous study. The variations of the terminal shock strength surely existed in the same shock capturing mode. Thus the total pressure recovery improved when the shock weakened. Author

A93-22690#
FLOW STABILITY ISSUES IN SUPERSONIC INLET FLOW ANALYSES
GERALD C. PAYNTER, DAVID W. MAYER, and ELLING TJONNELAND (Boeing Co., Seattle, WA) Jan. 1993 17 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0290) Copyright
The stability margin of a mixed compression supersonic inlet *is an important design feature needed to protect an aircraft from* inlet unstart due to disturbances from either the compressor face or the freestream. The Mach number distribution in the throat, the Mach number distribution at the normal shock, and the movement of the normal shock from the design position due to a disturbance characterize the stability margin of an inlet. One-dimensional analysis and two-dimensional Euler simulations of supersonic inlet flows were used to examine inlet stability properties. Good agreement was obtained between one-dimensional quasi-steady analysis results and time accurate Euler simulations for the translation of the normal shock due to a compressor face disturbance. Results from both the one-dimensional and the Euler analyses for the transient response of the normal shock to a disturbance from the compressor face seem qualitatively correct. Accounting for the change in bleed discharge coefficient across the normal shock was found to be important in the prediction of the normal shock translation due to a reduction in engine flow. Evaluation of the accuracy of the one-dimensional and the Euler analyses is needed prior to design support applications. Author

A93-22691#
PASSIVE CONTROL OF PRE-ENTRY SHOCK IN SUPERSONIC INTAKES
S. ROLSTON (Short Brothers, PLC, Nacelle Systems Div., Belfast, United Kingdom) and S. RAGHUNATHAN (Belfast, Queen's Univ., United Kingdom) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0291) Copyright
The feasibility of improving the intake performance of supersonic aircraft engine by passive control of preentry shock was investigated in experiments conducted on an intake in a small supersonic tunnel at a Mach number of 1.46. It was found that the preentry shock position could be controlled by positioning the injection slot. It was also found that passive control devices can reduce the shock interaction loss significantly with an improvement in the overall pressure recovery. I.S.

A93-22692#
EVALUATION OF A CFD CODE FOR ANALYSIS OF NORMAL-SHOCK TRAINS
A. R. ELMQUIST (United Technologies Research Center, East Hartford, CT) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0292) Copyright
A study was performed to evaluate the ability of CFD to analyze the flow through a normal-shock train. The CFD code used in this study was GASP-2.0 which solves the three-dimensional time-dependent Reynolds-averaged Navier-Stokes equations using a finite-volume approach. The current version of this code employs a Baldwin-Lomax algebraic turbulence model. In the present study, the code was modified to include Goldberg's backflow model to help resolve the turbulent boundary-layer separations characteristic of normal-shock-train flow. Experiments conducted by Carroll and Dutton were used as the test case. In these experiments, normal-shock trains were examined in a simple rectangular duct with an undisturbed Mach number of 1.61. Comparisons are made of axial wall pressure distributions, velocity profiles, skin friction distributions and Mach number contours. Results obtained in the present study show very good agreement with the data. The Goldberg back-flow model is shown to improve the ability of the analysis to represent the details of the flow in a normal-shock train. Author

A93-22693#
VALIDATION OF A NAVIER-STOKES CODE USING A (K,EPSILON) TURBULENCE MODEL APPLIED TO A THREE-DIMENSIONAL TRANSONIC CHANNEL
JULIETTE CAHEN (SNECMA, Moissy-Cramayel, France), VINCENT COUAILLIER, JEAN DELERY, and THIERRY POT (ONERA, Chatillon, France) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by DRET refs
(AIAA PAPER 93-0293) Copyright
The flow induced by a swept bump mounted on the lower wall of a transonic channel has been thoroughly analyzed on the basis of surface pressure measurements, surface flow visualizations and field measurements by a three-component LDV system. The same flow has been computed by a code solving the full time-averaged Navier-Stokes equations by a method using an explicit centered finite difference scheme applied to a finite volume approach. An algebraic model using the mixing length concept and the Jones-Launder (k,epsilon) transport equation model have been considered. Both models give a faithful prediction of the essential features of the flow; in particular the shock pattern forming in the channel is well predicted. However, the (k,epsilon) model shows a clear superiority in the prediction of the behavior of the interacting dissipative layers. Author

A93-22694*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A PARAMETRIC STUDY OF BLEED IN SHOCK BOUNDARY LAYER INTERACTIONS
A. HAMED, S. H. SHIH, and J. J. YEUAN (Cincinnati Univ., OH) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract AF-AFOSR-91-0101; NAG3-1213)
(AIAA PAPER 93-0294) Copyright

A numerical investigation was conducted to study the effect of bleed configuration on oblique-shock wave/turbulent boundary-layer interactions. Bleed is applied through a normal slot across the shock impingement location. The numerical solution to the compressible Navier-Stokes equations is obtained for the turbulent flow throughout the interaction zone and inside the bleed slot for bleed mass flow rates up to 57 percent of the boundary layer mass flow upstream of the interaction. The results indicate that the bleed slot performance improves as the slot width decreases and the length to width ratio increases. This is reflected as an increase in the bleed discharge coefficient and total pressure, and a reduction in the boundary layer momentum and displacement thickness downstream. Author

A93-23001*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
LDV FLOWFIELD MEASUREMENTS ON A STRAIGHT AND SWEPT WING WITH A SIMULATED ICE ACCRETION
M. B. BRAGG, M. F. KERHO, and A. KHODADOUST (Illinois Univ., Urbana) Jan. 1993 20 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG3-1134)
(AIAA PAPER 93-0300) Copyright

Simulated glaze ice accretion effects on a flowfield are presently studied for the case of a 3D semispan wing with NACA 0012 airfoil section on a rectangular untwisted planform. The model was tested at both zero-sweep and 30-deg sweep setting with four-beam/two-color LDV flowfield mapping. The comparison of LDV-measure velocity profiles with 3D Navier-Stokes predictions revealed correct trends, but with several differences that are attributable to the turbulence models and grid resolution used in the computations. O.C.

A93-23006*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
A COMPARISON OF HYPERSONIC FLIGHT AND PREDICTION RESULTS
KENNETH W. ILIFF and MARY F. SHAFER (NASA, Flight Research Center, Edwards, CA) Jan. 1993 42 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0311) Copyright

Aerodynamic and aerothermodynamic comparisons between flight and ground test for four hypersonic vehicles are discussed. The four vehicles are the X-15, the Reentry F, the Sandia Energetic Reentry Vehicle Experiment (SWERVE), and the Space Shuttle. The comparisons are taken from papers published by researchers active in the various programs. Aerodynamic comparisons include reaction control jet interaction on the Space Shuttle. Various forms of heating including catalytic, boundary layer, shock interaction and interference, and vortex impingement are compared. Predictions were significantly exceeded for the heating caused by vortex impingement (on the Space Shuttle OMS pods) and for heating caused by shock interaction and interference on the X-15 and the Space Shuttle. Predictions of boundary-layer state were in error on the X-15, the SWERVE, and the Space Shuttle vehicles. Author

A93-23007# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
APPLICATION OF CFD TO A GENERIC HYPERSONIC FLIGHT RESEARCH STUDY
MICHAEL J. GREEN, SCOTT L. LAWRENCE (NASA, Ames Research Center, Moffett Field, CA), ARTHUR D. DILLEY, RICHARD W. HAWKINS (Analytical Services and Materials, Inc.; NASA, Langley Research Center, Hampton, VA), MARY M. WALKER, and WILLIAM L. OBERKAMPF (Sandia National Labs., Albuquerque, NM) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0312) Copyright

Computational analyses have been performed for the initial assessment of flight research vehicle concepts that satisfy requirements for potential hypersonic experiments. Results were obtained from independent analyses at NASA Ames, NASA Langley, and Sandia National Labs, using sophisticated time-dependent Navier-Stokes and parabolized Navier-Stokes methods. Careful study of a common problem consisting of hypersonic flow past a slightly blunted conical forebody was undertaken to estimate the level of uncertainty in the computed results, and to assess the capabilities of current computational methods for predicting boundary-layer transition onset. Results of this study in terms of surface pressure and heat transfer comparisons, as well as comparisons of boundary-layer edge quantities and flow-field profiles are presented here. Sensitivities to grid and gas model are discussed. Finally, representative results are presented relating to the use of Computational Fluid Dynamics in the vehicle design and the integration/support of potential experiments. Author

A93-23011#
NUMERICAL SIMULATION OF FLOW PAST THE X24C REENTRY VEHICLE
DATTA GAITONDE and J. S. SHANG (USAF, Wright Lab., Wright-Patterson AFB, OH) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0319)

The present numerical investigation of complex flow past a reentry vehicle employs a high-resolution scheme under inviscid, laminar, and turbulent modeling assumptions at Mach 6 and 6-deg angle-of-attack; the Reynolds number was 5 million/ft, and emphasis was placed on the prediction accuracy of local and global quantities that are of prospective engineering value. While very good agreement with experiment was obtained for surface pressure data and for lift, using all three levels of modeling, the drag values and turbulent heat transfer profiles at several aircraft sections diverge modestly from experimental results. O.C.

A93-23012#
NUMERICAL SOLUTION OF INVISCID HYPERSONIC FLOW AROUND A CONICALLY-DERIVED WAVERIDER
G. O. STECKLEIN, G. A. HASEN (USAF, Inst. of Technology, Wright-Patterson AFB, OH), and D. GAITONDE (USAF, Wright Lab., Wright-Patterson AFB, OH) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Ohio Supercomputer Center refs
(AIAA PAPER 93-0320)

A 3D finite volume Euler equation solver utilizing spatial Roe-averaged, flux-difference splitting and a standard MacCormack explicit time integration scheme is employed to solve the inviscid flow field around a conically-derived waverider body. At the on-design flight condition (Mach 10, 100,000 ft standard altitude, zero angle of attack), solutions are compared with those obtained analytically utilizing hypersonic small disturbance theory. A study is performed using two grid generation methods and refinement levels to test the robustness and accuracy of this new 3D finite-volume numerical algorithm. R.E.P.

A93-23013*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SHOCK-DEPENDENT, THRUST WINGS FOR SUPERSONIC FLOW
JAMES L. PITTMAN (NASA, Langley Research Center, Hampton, VA) Jan. 1993 15 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0321) Copyright

A new wing concept which lowers the inviscid drag of a wing

in supersonic flow is described. The thrust-wing concept uses a secondary shock that occurs to the rear of the maximum thickness location to produce a significant aerodynamic thrust force from the rearward portion of the wing, thus reducing the inviscid drag. The evaluation of the thrust-wing concept is conducted on a delta-wing planform of differing sweep angles and thicknesses at Mach 1.60 over a wide range of lifting conditions. R.E.P.

A93-23014*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

FLOWFIELD COMPUTATIONS OVER THE SPACE SHUTTLE ORBITER WITH A PROPOSED CANARD AT A MACH NUMBER OF 5.8 AND 50 DEGREES ANGLE OF ATTACK

WILLIAM H. REUTER (U.S. Naval Postgraduate School, Monterey, CA), PIETER G. BUNING (NASA, Ames Research Center, Moffett Field, CA), and GARTH V. HOBSON (U.S. Naval Postgraduate School, Monterey, CA) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(AIAA PAPER 93-0322)

An effective control canard design to provide enhanced controllability throughout the flight regime is described which uses a 3D, Navier-Stokes computational solution. The use of canard by the Space Shuttle Orbiter in both hypersonic and subsonic flight regimes can enhance its usefullness by expanding its payload carrying capability and improving its static stability. The canard produces an additional nose-up pitching moment to relax center-of-gravity constraint and alleviates the need for large, lift-destroying elevon deflections required to maintain the high angles of attack for effective hypersonic flight. O.G.

A93-23015#

CFD ANALYSIS OF HYPERSONIC CHEMICALLY REACTING FLOWFIELDS AROUND A GENERIC SHAPE

G. BRENNER (DLR, Inst. for Theoretical Fluid Mechanics, Goettingen, Germany), J.-V. HACHEMIN, E. C. HUGUES, A. LUC, and J.-L. VERANT (ONERA, Chatillon, France) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(AIAA PAPER 93-0323) Copyright

A numerical study of an axisymmetric equivalent body of the HERMES space vehicle has been made for a reentry point at Mach 25 with both Thin Layer Navier-Stokes and Parabolized Navier-Stokes solvers for perfect gas and chemical nonequilibrium modelizations. A particular attention is focused on the viscous interaction in the region of a deflected flap. The effect of the wall catalycity is investigated. Meanwhile, a particular care has been taken for physical modelization coherence in order to compare both approximated Navier-Stokes methods. The structure of the flow given by the TLNS is analyzed for several deflection angles. The flow field in the vicinity of the flap hinge area is predicted by the PNS with a plane-by-plane iterative algorithm. PNS computations are compared to the TLNS solutions and detailed investigations led to consider Parabolized approximation as an accurate and efficient numerical tool for design studies, despite the separation region. Author

A93-23022*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

3D EULER FLOW SOLUTIONS USING UNSTRUCTURED CARTESIAN AND PRISMATIC GRIDS

JOHN E. MELTON (NASA, Ames Research Center, Moffett Field, CA), SHISHIR A. PANDYA, and JOSEPH L. STEGER (California Univ., Davis) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(AIAA PAPER 93-0331) Copyright

A hyperbolic prismatic grid generation technique is combined with a background Cartesian grid for the study of inviscid three-dimensional flows. The mathematics of the hyperbolic prismatic grid generation algorithm are described, and some simple inviscid demonstration cases are presented. By combining the simplicity of the Cartesian background grid with the geometric flexibility and computational efficiencies inherent to prismatic grids, this approach shows promise for improving computational aerodynamic simulations. Author

A93-23026#

DISCONTINUOUS GALERKIN FINITE ELEMENT METHOD FOR TWO DIMENSIONAL CONSERVATION LAWS

SAN-YIH LIN, YAN-SHIN CHIN, YUNG-FU DUNG, CHIH-CHIANG HONG, YUH-YING WANG, and CHIH-HSIN KO (National Cheng Kung Univ., Tainan, Taiwan) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(AIAA PAPER 93-0337) Copyright

A finite element method for the solutions of Euler and Navier-Stokes Equations has been developed to study fluid dynamics. The spatial discretization involves the discontinuous Galerkin finite element method with Lax-Friedrichs flux method. The temporal discretization involves the explicit Runge-Kutta time integrations. To simulate flows over moving bodies, a dynamic mesh algorithm is applied and to compute flows over three dimensional cones, a two-dimensional conical-flow assumption is included in this study. The inviscid flows passing through a channel with circular arc bump, through the NACA0012 airfoil and the laminar flows over a flat plate with shock interaction are investigated to confirm the accuracy and convergence of the finite element method. To further prove the reliability and capability of the present method, the inviscid/viscous results for conical flows over three-dimensional cones and for unsteady flows over the pitching NACA0012 airfoil are compared to the numerical and experimental data given in related papers and reports. Author

A93-23027#

UNSTEADY COMPRESSIBLE AIRFOIL AERODYNAMICS USING AN ADAPTIVE TIME-DISCONTINUOUS GLS FINITE ELEMENT METHOD

B. E. WEBSTER, M. S. SHEPHARD, Z. RUSAK, and J. E. FLAHERTY (Rensselaer Polytechnic Inst., Troy, NY) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(Contract DAAL03-88-C-0004)

(AIAA PAPER 93-0339) Copyright

An adaptive time-discontinuous Galerkin Least Squares (GLS) finite element method for unsteady compressible airfoil aerodynamics is described. The time-discontinuous GLS finite element method is particularly suitable to handle problems with multiple relative motion. The mesh enrichment procedure developed to enable the solution process to be spatially adaptive (h-refinement) is edge based and stores no mesh enrichment history. Correlated steady and unsteady transonic airfoil calculations are presented. Author

A93-23030*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

TRANSITION ON A SHARP CONE AT HIGH ENTHALPY - NEW MEASUREMENTS IN THE SHOCK TUNNEL T5 AT GALCIT

P. GERMAIN, E. CUMMINGS, and H. HORNUNG (California Inst. of Technology, Pasadena) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(Contract NAG1-1209; F49610-92-J-0110)

(AIAA PAPER 93-0343) Copyright

An exploratory study of the laminar, transitional and turbulent boundary layer on a slender cone in hypervelocity flow was conducted in the high-enthalpy shock tunnel T5. A novel flow visualization technique using sodium seeding to increase the sensitivity of conventional interferometric techniques by resonant enhancement of the refractivity of the medium was developed to study its structure. The experiments were designed to cover a large range of specific reservoir enthalpy, ranging from the perfect-gas region to the range where significant oxygen and some nitrogen dissociation and recombination effects may be expected in the boundary layer. Surface heat flux measurements indicate that the transition Reynolds number is approximately the same as

that observed in cold hypersonic flow in conventional continuous flow facilities, but significantly lower than that observed in 'quiet' tunnels. No significant effect of reservoir specific enthalpy on transition was observed. The heat flux distribution showed differences between the air and the nitrogen experiments in the laminar regime. These are consistent with the presence of recombination of oxygen at the wall. This view is supported by the fact that this effect is absent in the low-enthalpy region, where the heat flux distribution agrees with the similarity theory. Author

A93-23063*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
WALL PRESSURE FLUCTUATIONS BENEATH SWEPT SHOCK WAVE/BOUNDARY LAYER INTERACTIONS
S. GARG and G. S. SETTLES (Pennsylvania State Univ., University Park) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG1-1070)
(AIAA PAPER 93-0384) Copyright

An experimental research program providing basic knowledge and establishing a database on the fluctuating pressure loads produced on aerodynamic surfaces beneath 3D shock wave/boundary layer interactions is presented. A turbulent boundary layer on a flat plate is subjected to interactions with swept planar shock waves generated by sharp fins at angle of attack. Measurements are made for the first time in the aft areas of these interactions, showing fluctuating pressure levels as high as 160 dB. R.E.P.

A93-23064*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CONTROL OF PRESSURE FLUCTUATIONS IN THE REATTACHMENT REGION OF A SUPERSONIC FREE SHEAR LAYER
J. POGGIE and A. J. SMITS (Princeton Univ., NJ) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG1-1072; AF-AFOSR-90-0217)
(AIAA PAPER 93-0385) Copyright

Measurements of wall pressure fluctuations were made as part of an ongoing program to investigate the control of a turbulent, reattaching shear layer at Mach 2.9. The flow was disturbed near separation by air injection normal to the plane of the shear layer. This perturbation was found to dramatically increase the intensity of pressure fluctuations in the vicinity of reattachment. A local increase in shear layer growth rate was also observed in the perturbed flow. Author

A93-23065#
EULER COMPUTATIONS OF ROTOR-STATOR INTERACTION IN TURBOMACHINERY CASCADES USING ADAPTIVE TRIANGULAR MESHES
J. Y. TREPANIER, M. PARASCHIVOIU, and M. REGGIO (Ecole Polytechnique, Montreal, Canada) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0386) Copyright

The present paper describes a method for the numerical simulation of unsteady two-dimensional inviscid compressible flow in turbomachinery cascades. The time-dependent Euler equations are solved using a finite-volume method, together with an approximate Riemann solver based on Roe's scheme. An unstructured triangular grid connected in a cyclic data structure is combined with a dynamic mesh algorithm, allowing a direct handling of the rotor's movement. Unsteady results are presented for a cold air turbine. The mean velocity field is compared with experimental data. This computation demonstrates the adequacy of the proposed methodology for unsteady flows simulations in turbomachinery cascades. Author

A93-23066*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A HYBRID STRUCTURED-UNSTRUCTURED GRID METHOD FOR UNSTEADY TURBOMACHINERY FLOW COMPUTATIONS
SANJAY R. MATHUR (Iowa State Univ. of Science and Technology, Ames), NATERI K. MADAVAN (MCAT Inst.; NASA, Ames Research Center, Moffett Field, CA), and R. G. RAJAGOPALAN (Iowa State Univ. of Science and Technology, Ames) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by U.S. Navy refs
(Contract NCA2-541)
(AIAA PAPER 93-0387) Copyright

A hybrid grid technique for the solution of 2D, unsteady flows is developed. This technique is capable of handling complex, multiple component geometries in relative motion, such as those encountered in turbomachinery. The numerical approach utilizes a mixed structured-unstructured zonal grid topology along with modeling equations and solution methods that are most appropriate in the individual domains, therefore combining the advantages of both structured and unstructured grid techniques. R.E.P.

A93-23067#
SINGLE PASSAGE EULER ANALYSIS OF OSCILLATING CASCADE UNSTEADY AERODYNAMICS FOR ARBITRARY INTERBLADE PHASE ANGLE
JAMES M. WOLFF and SANFORD FLEETER (Purdue Univ., West Lafayette, IN) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract AF-AFOSR-91-0251)
(AIAA PAPER 93-0389) Copyright

The unsteady flow field through an harmonically oscillating cascade of airfoils is investigated using a time-marching Euler code implemented on a deforming C-grid. Various methods of calculating the boundary conditions are considered, with special attention paid to the unsteady periodic boundary conditions and reducing computer resource requirements. The Euler code is then used to predict the unsteady aerodynamics for both translational and torsional cascade oscillations for several cascade flow geometries. A flat plate cascade is used to verify the flow solver with linear theory predictions. A typical compressor rotor configuration is used to introduce nonlinear effects. The effect of a strong normal shock with varied amplitudes of oscillation demonstrates the nonlinear behavior of the periodic boundary conditions and helps to define the limiting conditions for linearized analyses. Author

A93-23068#
THREE-DIMENSIONAL NAVIER-STOKES ANALYSIS OF THE TIP CLEARANCE FLOW IN LINEAR TURBINE CASCADES
JONG-SHANG LIU and RICCARDO BOZZOLA (Textron Lycoming, Turbine Engine Div., Stratford, CT) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Textron Lycoming refs
(AIAA PAPER 93-0391) Copyright

A three-dimensional viscous flow code was used to study the tip clearance flow in linear turbine cascades. Two test cases with detailed measurements were used for validation. The flow properties inside the tip gap, such as static pressure, velocity, and angle, were compared with the data. The blade loading at different span locations and the downstream flow field properties, such as loss and angle, were also compared with the data. The clearance flow phenomena, such as leakage vortex, changing of loss distribution, and flow undertaking, were predicted by the numerical code. This code can not only be used as an analysis tool to study tip clearance effects in real turbine blade rows but can also be used as a design tool to design the turbine components. Author

A93-23240# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SURFACE ROUGHNESS DUE TO RESIDUAL ICE IN THE USE OF LOW POWER DEICING SYSTEMS
JAIWON SHIN and THOMAS H. BOND (NASA, Lewis Research

Center, Cleveland, OH) Jan. 1993 15 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15338 refs
(Contract RTOP 505-68-10)
(AIAA PAPER 93-0031) Copyright

Thicknesses of residual ice are presented to provide information on surface contamination and associated roughness during deicing events. Data was obtained from low power ice protection systems tests conducted in the Icing Research Tunnel at NASA Lewis Research Center (LeRC) with nine different deicing systems. Results show that roughness associated with residual ice is not characterized by uniformly distributed roughness. Results also show that deicing systems require a critical mass of ice to generate a sufficient expelling force to remove the ice. Author

A93-23247*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN OVERVIEW OF SHED ICE IMPACT STUDIES IN THE NASA LEWIS ICING RESEARCH TUNNEL
RANDALL K. BRITTON (Sverdrup Technology, Inc., Brook Park, OH) and THOMAS H. BOND (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15404 refs
(AIAA PAPER 93-0301) Copyright

One of the areas of active research in commercial and military rotorcraft is directed toward developing the capability of sustained flight in icing conditions. The emphasis to date has been on the accretion and subsequent shedding of ice in an icing environment, where the shedding may be natural or induced. Historically, shed-ice particles have been a problem for aircraft, particularly rotorcraft. Because of the high particle velocities involved, damage to a fuselage or other airframe component from a shed-ice impact can be significant. Design rules for damage tolerance from shed-ice impact are not well developed because of a lack of experimental data. Thus, NASA Lewis (LeRC) has begun an effort to develop a database of impact force and energy resulting from shed ice. This effort consisted of a test of NASA LeRC's Model Rotor Test Rig (MRTR) in the Icing Research Tunnel (IRT). Both natural shedding and forced shedding were investigated. Forced shedding was achieved by fitting the rotor blades with Small Tube Pneumatic (STP) deicer boots manufactured by BF Goodrich. A detailed description of the test is given as well as the design of a new impact sensor which measures the force-time history of an impacting ice fragment. A brief discussion of the procedure to infer impact energy from a force-time trace are required for the impact-energy calculations. Recommendations and future plans for this research area are also provided. Author

A93-23253#
EXPANDING THE WAVERIDER DESIGN SPACE USING GENERAL SUPERSONIC AND HYPERSONIC GENERATING FLOWS
FREDERICK FERGUSON and JOHN D. ANDERSON, JR. (Maryland Univ., College Park) Jan. 1993 16 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0505) Copyright

Waveriders have been constructed from hypersonic flowfields behind arbitrary three dimensional shock shapes using a special spatial marching finite difference approach. This routine exploits the simplicity and efficiency of spatial marching techniques and the accuracy of the method of characteristics, and greatly simplifies the waverider design process. The stream surfaces behind the shock shapes form the compression surface for a new family of waveriders, providing greatly needed flexibility in the design and optimization of such vehicles. Emphasis is placed on the influence of the shock shape and its relationship to the aerodynamic characteristics of the resulting waverider. A systematic approach based on the direct search Rosenbrock optimization technique is developed in an effort to carve waveriders with optimal aerodynamic quantities for given dimension and free stream conditions. Waveriders carved from arbitrary oblique and axisymmetric shock waves are evaluated and validated against those constructed using conventional numerical techniques. Finally, a new class of waveriders carved from arbitrary three dimensional shock shapes are presented and discussed. Author

A93-23254# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ENGINE/AIRFRAME INTEGRATION FOR WAVERIDER CRUISE VEHICLES
MARK J. LEWIS and NARUHISA TAKASHIMA (Maryland Univ., College Park) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NCA2-611; NAG1-1192)
(AIAA PAPER 93-0507) Copyright

Engine-airframe integrated hypersonic waveriders have been optimized previously for both cruising flight and accelerators using inverse design flowfields to provide desirable aerodynamic performance and inlet properties. With engine installation, cruisers retain the high L/D advantages of the basic waverider form. To provide an understanding of wavcrider optimizer trends, an analytical development is presented which includes the presentation of a simplified model of a generic waverider shape. The model is shown to have good agreement with computational results, and it is used to demonstrate engineering tradeoffs in L/D, volume, and volume efficiency. Based on the demonstrated performance trends, and considering the desirability of uniform inlet flow, an improved waverider shape for engine-airframe integration is proposed using a hybrid cone-wedge generating flowfield. Author

A93-23264*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
JUNCTURE FLOW IMPROVEMENT FOR WING/PYLON CONFIGURATIONS BY USING CFD METHODOLOGY
LIE-MINE GEA (McDonnell Douglas Aerospace Systems Co., Long Beach, CA), WEI J. CHYU, MICHAEL W. STORTZ (NASA, Ames Research Center, Moffett Field, CA), and CHUEN-YEN CHOW (Colorado Univ., Boulder) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NCC2-630)
(AIAA PAPER 93-0522)

Transonic flow field around a fighter wing/pylon configuration was simulated by using an implicit upwinding Navier-Stokes flow solver (F3D) and overset grid technology (Chimera). Flow separation and local shocks near the wing/pylon junction were observed in flight and predicted by numerical calculations. A new pylon/fairing shape was proposed to improve the flow quality. Based on numerical results, the size of separation area is significantly reduced and the onset of separation is delayed farther downstream. A smoother pressure gradient is also obtained near the junction area. This paper demonstrates that computational fluid dynamics (CFD) methodology can be used as a practical tool for aircraft design. Author

A93-23265#
F-14A AIRCRAFT LOW-SPEED MANEUVERING AERODYNAMICS
TSZE C. TAI (U.S. Navy, Naval Surface Warfare Center, Bethesda, MD) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by U.S. Navy refs
(AIAA PAPER 93-0523) Copyright

The F-14A aircraft low-speed arodynamics in a seabase interface environment is simulated by using a multi-zone, thin-layer Navier-Stokes method. Two test cases are considered: one with an uniform freestream of the aircraft landing speed, Mach 0.18, at various angles of attack, and the other with a nonuniform freestream represented by an airwake profile behind a ship. Without the influence of ship's airwake, the aerodynamic lift is stable in the angle-of-attack range between eight and 12 degrees, although massive flow separation occurs for angle of attack beyond eight degrees. The ship's airwake has an adverse effect on aircraft lift.

The decrease in lift is believed to be caused by the worsened flow separation, airwake downwash velocity, and the resulting slower freestream for the aircraft. Author

A93-23266#
THE INFLUENCE OF THE BOUNDARY LAYER ON THE SUBSONIC NEAR-WAKE OF A FAMILY OF BLUFF BODIES
CHARLES W. ALCORN and COLIN P. BRITCHER (Old Dominion Univ., Norfolk, VA) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Inst. for Computational and Applied Mechanics refs
(AIAA PAPER 93-0525) Copyright

The relationship between the boundary-layer momentum thickness and the subsonic bluff-body base pressure is examined for axisymmetric and nonaxisymmetric bluff bodies, with particular attention given to the effect of various slanted-base geometries on the upstream parameters. The model tested was a slanted-base ogive cylinder, modified to maintain natural laminar boundary-layer flow. Tests were carried out for a range of slant angles in a low-speed unpressurized wind tunnel, with measurements including the base pressures, the wake stagnation point location, the incoming boundary layer velocity profiles, and the wake periodicity. It was found that, despite large variations in the base pressure coefficient with varying Reynolds number or the boundary layer trip location, all base pressure measurements collapsed onto single curves when plotted against incoming boundary layer momentum thickness. I.S.

A93-23267*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THREE-DIMENSIONAL SUPERSONIC VORTEX BREAKDOWN
OSAMA A. KANDIL, HAMDY A. KANDIL (Old Dominion Univ., Norfolk, VA), and C. H. LIU (NASA, Langley Research Center, Hampton, VA) Jan. 1993 16 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG1-994)
(AIAA PAPER 93-0526) Copyright

Three-dimensional supersonic vortex-breakdown problems in bound and unbound domains are solved. The solutions are obtained using the time-accurate integration of the unsteady, compressible, full Navier-Stokes (NS) equations. The computational scheme is an implicit, upwind, flux-difference splitting, finite-volume scheme. Two vortex-breakdown applications are considered in the present paper. The first is for a supersonic swirling jet which is issued from a nozzle into a supersonic uniform flow at a lower Mach number than that of the swirling jet. The second is for a supersonic swirling flow in a configured circular duct. In the first application, an extensive study of the effects of grid fineness, shape and grid-point distribution on the vortex breakdown is presented. Four grids are used in this study and they show a substantial dependence of the breakdown bubble and shock wave on the grid used. In the second application, the bubble-type and helix-type vortex breakdown have been captured. Author

A93-23268#
CALCULATION OF THE FLOWFIELD AROUND AN AIRFOIL WITH SPOILER
HONAM OK and D. S. EBERHARDT (Washington Univ., Seattle) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0527) Copyright

The structure and characteristics of the flowfield around an airfoil with a spoiler is investigated by simulating the flowfield in a time-accurate manner, using efficient incompressible Navier-Stokes solvers based on the method of pseudocompressibility extended to an unsteady problem. The basic airfoil model is based on a Boeing advanced transport research airfoil. The average lift and drag were computed for different angles of attack at a spoiler deflection angle fixed at 60 deg. It was found that, as the angle of attack increases, the separation point of the hinge bubble moves upstream, but the flow reattaches at the same point regardless of the angle of attack. The Strouhal number based on the spoiler projection height was calculated from the time history of the lift and drag coefficients, and was found to be in excellent agreement with the experiment. I.S.

A93-23269*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN INSTALLED NACELLE DESIGN METHOD USING MULTIBLOCK EULER SOLVER
H. C. CHEN (Boeing Commercial Airplane Group, Seattle, WA) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS1-18703)
(AIAA PAPER 93-0528) Copyright

An efficient multiblock Euler design method was developed for designing a nacelle installed on geometrically complex airplane configurations. This approach employed a design module based on a direct iterative surface curvature method developed at NASA-Langley. A multiblock Euler flow solver was used for computing flow around complex geometries. The flow solver used a finite-volume formulation with explicit time-stepping to solve the Euler equations. It used a multiblock version of the multigrid method to accelerate the convergence of the calculations. The design module successively updated the surface geometry to reduce the difference between the computed and target pressure distributions. In the flow solver, the change in surface geometry was simulated by applying surface transpiration boundary conditions to avoid repeated grid generation during design iterations. Smoothness of the designed surface was ensured by alternate application of streamwise and circumferential smoothings. Author

A93-23270*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
APPLICATION OF A NAVIER-STOKES AEROELASTIC METHOD TO IMPROVE FIGHTER WING PERFORMANCE AT MANEUVER FLIGHT CONDITIONS
DAVID M. SCHUSTER (Lockheed Engineering and Sciences Co., Hampton, VA) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS1-19000)
(AIAA PAPER 93-0529) Copyright

An aeroelastic analysis method, based on three-dimensional Navier-Stokes equation aerodynamics, has been applied to improve the performance of fighter wings operating at sustained maneuver flight conditions. The scheme reduces the trimmed pressure drag of wings performing high-g maneuvers through a simultaneous application of control surface deflection and aeroelastic twist. The aerodynamic and structural interactions are decoupled by assuming an aeroelastic twist mode shape and optimizing the aerodynamic performance based on this aeroelastic mode. The wing structural stiffness properties are then determined through an inverse scheme based on the aerodynamic loads and desired twist at the maneuver flight condition. The decoupled technique is verified by performing a fully coupled aeroelastic analysis using the maneuver flight conditions and the optimized structural stiffness distributions. Author

A93-23272#
NUMERICAL SIMULATION OF THREE-DIMENSIONAL SUPERSONIC FLOWS USING EULER AND BOUNDARY LAYER SOLVERS
F. GAIBLE, R. CARIOU (Aerospatiale, Verrieres-le-Buisson, France), and R. HOUDEVILLE (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0531) Copyright

In order to calculate at a low cost, the flow around two supersonic configurations, an efficient Euler solver (FLU3C) is utilized together with a boundary layer calculation code. This code solves the 3D unsteady Euler equations for a perfect gas with a finite volume approach. Significant properties of the viscous region, e.g., transition to turbulence and separation lines, are obtained at a low cost. R.E.P.

A93-23273#
THE DESIGN OF OPTIMIZED AIRFOILS IN SUBCRITICAL FLOW
J. OLEJNICZAK and A. S. LYRINTZIS (Minnesota Univ., Minneapolis) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Univ. of Minnesota refs
(AIAA PAPER 93-0532) Copyright

An airfoil design method based on optimization procedures in computational aerodynamics is presented. This paper extends the method to include subcritical compressible flow and a modified Stratford distribution to alleviate the hard stall typical of Stratford type airfoils. A procedure for optimizing the drag is also presented based on the Squire-Young drag formula. The performance characteristics of this airfoil are then tested with a compressible panel method and boundary layer solver. Results for both incompressible and compressible flow have generated airfoils which generate more lift and less drag than other comparable airfoils. High-lift airfoils which display a smooth stall region have also been developed which hold promise for general aviation use. In addition these airfoils offer the potential of improved performance in applications such high-endurance aircraft, propellers, fans, and windmill blades where high lift-to-drag ratios are desired. A specific example of an airfoil designed for a wind turbine is presented and compared to an existing aitfoil. Author

A93-23289#
THREE-DIMENSIONAL FLOW STRUCTURE ON DELTA WINGS AT HIGH ANGLE-OF-ATTACK - EXPERIMENTAL CONCEPTS AND ISSUES
DONALD ROCKWELL (Lehigh Univ., Bethlehem, PA) Jan. 1993 19 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract F49620-92-J-0065; AF-AFOSR-91-0055)
(AIAA PAPER 93-0550) Copyright

This assessment addresses the physics of unsteady flow past swept wings at high angle-of-attack. Emphasis is on principles of flow control, accounting for the inherent time-scales of: the feeding sheet; the leading-edge vortex exhibiting breakdown (bursting); the surface boundary layer undergoing separation; and stall regions evolving from vortex breakdown and surface separation. Unresolved issues are posed, with emphasis on the instantaneous flow structure and its interpretation using topological concepts. Author

A93-23290*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
MEASUREMENTS IN THE NEAR-FIELD OF A TURBULENT WINGTIP VORTEX
JIM S. CHOW (Stanford Univ., CA), GREGORY G. ZILLIAC (NASA, Ames Research Center, Moffett Field, CA), and PETER BRADSHAW (Stanford Univ., CA) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0551) Copyright

The roll-up of a wingtip vortex, at Reynold's number based on chord of 4.6 million, was examined with emphasis on suction side and near wake measurements. Surface oil flow and laser smoke flow studies are performed, demonstrating the highly 3D nature of the flow around the wingtip, the formation of the feeding sheet, and the viscous core region of the vortex. Flow visualization and correlation measurements show that meandering of the vortex is small and does not appreciably contribute to the turbulence measurements. R.E.P.

A93-23292*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
STREAMWISE VORTEX MEANDER IN A PLANE MIXING LAYER
RICHARD L. LEBOEUF (NASA/Stanford Center for Turbulence Research, CA) and RABINDRA D. MEHTA (NASA, Ames Research Center, Moffett Field; Stanford Univ, CA) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NCC2-55)
(AIAA PAPER 93-0553) Copyright

Previous measurements in a two-stream plane mixing layer have shown that the mean streamwise vorticity decays monotonically with downstream distance such that it is absent in the far-field (self-similar) region. It was not clear at that time if this measured decay was a result of actual vortex diffusion or increasing vortex meander within the mixing layer. The present experimental study was conducted in order to determine the existence of streamwise vortex meander in a mixing layer, and if present, its significance on the measured properties. The dependence of the velocity cross-correlation on the fixed probe location is considered a good indicator of the stationarity of the streamwise vortex location. The cross-correlation measurements obtained here indicate that the spanwise meander is negligible while the transverse apparent meander (normal to the plane of the mixing layer) is relatively large. Author

A93-23293#
NUMERICAL SIMULATION OF DELTA-WING ROLL
RAYMOND E. GORDNIER and MIGUEL R. VISBAL (USAF, Wright Lab., Wright-Patterson AFB, OH) Jan. 1993 16 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0554)

This paper presents computations of the flowfield around an 80 deg sweep delta wing undergoing a constant roll-rate maneuver from 0 deg to 45 deg. The governing equations for the problem are the unsteady three-dimensional Navier-Stokes equations. The equations are solved using the implicit, approximately-factored algorithm of Beam-Warming. Fixed roll angle results are also presented and compared with experimental measurements to demonstrate the ability of the numerical technique to accurately capture the flowfield around a rolled delta wing. The dynamical behavior of the vortex position and strength, as well as its corresponding effect on surface pressure, lift and roll moment are described. A simple, quasi-static explanation of this vortex behavior based on effective angle of attack and sideslip angle is proposed. Author

A93-23294#
VORTEX BREAKDOWN OVER DELTA WINGS IN UNSTEADY FREE STREAM
ISMET GURSUL (Cincinnati Univ., OH) and CHIH-MING HO (California Univ., Los Angeles) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract F49620-88-C-0061)
(AIAA PAPER 93-0555) Copyright

Vortex breakdown over delta wings in unsteady free stream was investigated in a vertical unsteady water channel. If the vortex breakdown location is away from the trailing-edge and closer to the apex in steady free stream, the unsteadiness does not strongly affect the burst position for the same angle of attack. Otherwise, the breakdown may appear suddenly at an upstream location during the acceleration of the free stream, depending on the frequency and amplitude. Phase-averaged LDA velocity measurements show that the swirl angle and circulation are not influenced by breakdown. Since the swirl angle remains constant, it is suggested that the time-dependent nature of burst position is due to the relative variations in pressure gradient on the wing surface, which is expected to be more important near the trailing-edge. Author

A93-23340#
PRELIMINARY ASSESSMENT OF TUNNEL WALL INTERFERENCE IN THE NDA CRYOGENIC WIND TUNNEL
YUTAKA YAMAGUCHI, MASAHIRO YOROZU, TADASHI SAKAUE, and TERUO SAITO (National Defense Academy, Yokosuka, Japan) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0421) Copyright

As the second stage of a preliminary cryogenic airfoil testing

program, the test section interference of the NDA cryogenic tunnel was evaluated. A R4 airfoil model, which has the chord length of 12 cm, and the aspect ratio of 0.5, was tested in the range of Mach number and that of Reynolds number, 0.5 to 0.75, 7 million to about 11 million, respectively. The experimental results were corrected with empirical wall interference correction methods, the Blackwell method for the top and bottom walls, and the Barnwell-Sewall method for side wall boundary layers. This preliminary evaluation showed that the side wall boundary layers dominate the tunnel wall interference of the present cryogenic tunnel, and there may be some possibility of utilizing the tunnel for performing 2D airfoil tests if more precise wall interference parameters are obtained. Author

A93-23349#
UNSTEADY VORTEX DYNAMICS AND SURFACE PRESSURE TOPOLOGIES ON A PITCHING WING
SCOTT J. SCHRECK and HANK E. HELIN (U.S. Air Force Academy, Colorado Springs, CO) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0435)
A straight wing having a NACA 0015 cross section and rectangular planform was attached to a circular splitter plate. This configuration was pitched at constant rate to angles exceeding the static stall angle. The unsteady, vortex dominated flow that developed over the wing and splitter plate was characterized in detail using surface pressure measurements and flow visualization. Both types of data showed that the leading edge vortex underwent profound three-dimensional alterations to cross section and convection over the entire wing span. These modifications to leading edge vortex structure and kinematics were correlated with prominent spanwise variations in force coefficients. When appropriately dissected, visualization results and pressure data suggested physical mechanisms to account for these three-dimensional modifications to unsteady forces and surface pressures. Author

A93-23350#
A STUDY OF FLOW SEPARATION ON AN OSCILLATING FLAP AT MACH NUMBER 2.4
MICHAEL D. COON and GARY T. CHAPMAN (California Univ., Berkeley) Jan. 1993 16 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0436) Copyright
Measurements of unsteady wall pressures have been made in the turbulent boundary layer just upstream of the hinge line of an oscillating flap. The flap, which creates a highly three-dimensional compression corner flowfield, was oscillated in fully attached, crossing incipient separation, and fully separated flow regimes over a range of frequencies. It was found that a substantial lag was produced when oscillating across the point of incipient separation. This dynamic hysteresis was much less in the fully separated case and negligible in the fully attached case. Author

A93-23351# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ESTIMATION OF UNSTEADY LIFT ON A PITCHING AIRFOIL FROM WAKE VELOCITY SURVEYS
K. B. M. Q. ZAMAN, J. PANDA (NASA, Lewis Research Center, Cleveland, OH), and C. L. RUMSEY (NASA, Langley Research Center, Hampton, VA) Jan. 1993 15 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-14791 refs
(Contract RTOP 505-52-62)
(AIAA PAPER 93-0437) Copyright
The results of a joint experimental and computational study on the flowfield over a periodically pitched NACA0012 airfoil, and the resultant lift variation, are reported in this paper. The lift variation over a cycle of oscillation, and hence the lift hysteresis loop, is estimated from the velocity distribution in the wake measured or computed for successive phases of the cycle. Experimentally, the estimated lift hysteresis loops are compared with available data from the literature as well as with limited force balance measurements. Computationally, the estimated lift variations are compared with the corresponding variation obtained from the surface pressure distribution. Four analytical formulations for the lift estimation from wake surveys are considered and relative successes of the four are discussed. Author

A93-23352#
INITIAL ACCELERATION EFFECTS ON THE FLOW FIELD DEVELOPMENT AROUND RAPIDLY PITCHING AIRFOILS
C. P. GENDRICH, M. M. KOOCHESFAHANI (Michigan State Univ., East Lansing), and M. R. VISBAL (USAF, Wright Lab., Wright-Patterson AFB, OH) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract AF-AFOSR-89-0417; F49620-86-C-0127)
(AIAA PAPER 93-0438)
Computational results are presented to show how the acceleration period at the start of constant pitch rate trajectories affects the dynamic stall process. Large amplitude motions were studied on the basis of an NACA 0012 airfoil pitching about the quarter-chord axis. The initial acceleration is observed to affect the integrated loads, the surface pressure distribution, and the evolution of reversed flow regions just above the surface of the airfoil only during the acceleration period and for a relatively short time (t not more than 0.25 tau) afterwards. After that time, all of these quantities only depend on the instantaneous angle of attack for a given pitch rate. These conclusions are consistent with previous experimental observations indicating that the onset of leading edge separation and the subsequent development of the dynamic stall vortex is not influenced by the initial motion history for the range of parameters studied. Author

A93-23353#
ACTIVE CONTROL OF THE SHEAR LAYER ON A STATIC AIRFOIL
J. A. LOVATO and T. R. TROUTT (Washington State Univ., Pullman) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by USAF refs
(AIAA PAPER 93-0442)
The shear layer over a static NACA-0015 airfoil is investigated under natural and actively forced conditions. Specific focus is placed on evaluating the physical development of the large-scale shear layer structures and their response to either external acoustic or internal-tangential pulsed air control. Results show that the airfoil shear layer responds to the active forcing akin to a free shear layer. The flow is most responsive to control at frequencies coupled with the natural shear layer vortex passage frequencies. External acoustic forcing at the most receptive, or fundamental, frequencies leads to inhibition of vortex pairing, and thus to a delay of shear layer growth, and forcing at the corresponding subharmonics induced rapid vortex pairing and subsequent shear layer growth. Active control using internal tangential pulsed-air input is effective in reducing flow separation, increasing the maximum lift coefficient by 10 percent, and delaying aerodynamic stall. Author

A93-23386#
AERODYNAMIC ANALYSIS OF FLAPPING WING PROPULSION
MAX F. PLATZER, KERRIN S. NEACE, and CHUNG-KIANG PANG (U.S. Naval Postgraduate School, Monterey, CA) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by U.S. Navy refs
(AIAA PAPER 93-0484) Copyright
A panel code is described that permits the systematic study of the thrust and lift characteristics produced by oscillating airfoils and airfoil combinations in incompressible inviscid flow. Results are given for pitching or plunging airfoils and airfoil combinations. An evaluation is made of the propulsive efficiencies and of the interference effects. Comparisons with flat-plate theory and with experiments by W. Schmidt, McKinney and DeLaurier, and Freymuth show favorable agreement. R.E.P.

A93-23387*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
HIGH ACCURACY COMPUTATION OF FLUID-STRUCTURE INTERACTION IN TRANSONIC CASCADES
ALEXANDER BOSCHITSCH and TODD QUACKENBUSH (Continuum Dynamics, Inc., Princeton, NJ) Jan. 1993 15 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS3-26064)
(AIAA PAPER 93-0485) Copyright

A coupling strategy for simulating fluid-structure interaction phenomena is formulated and applied to the prediction of flutter in transonic cascades. The flow is governed by the Euler equations and discretized using a finite volume flux-splitting scheme. The structure is modeled using an isoparametric finite element formulation. The coupling strategy successfully reconciles these two formulations at the fluid-structure interface by enforcing both kinematic and kinetic boundary conditions. In particular, the conservation laws applicable to the combined fluid-structure system are preserved across the interface. Since the primary mechanism driving aeroelastic phenomena involves energy exchange occurring at the interface, this highly accurate coupling mechanism is believed to improve the predictive capability of the scheme. The coupled equations are advanced simultaneously in time using an implicit time integration method. Results obtained using the coupling method are presented for cascade geometries operating in transonic flow. Author

A93-23533* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THREE-DIMENSIONAL HYPERSONIC SHOCK WAVE/TURBULENT BOUNDARY-LAYER INTERACTIONS
M. I. KUSSOY and K. C. HORSTMAN (Eloret Inst., Palo Alto, CA) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 8, 9. Abridged. refs
(Contract NCC2-452)
Copyright

Experimental data for a series of three-dimensional shock wave/turbulent boundary-layer interaction flows at Mach 8.2 are presented. The test bodies, composed of sharp fins fastened to a flat plate test surface, were designed to generate flows with varying degrees of pressure gradient, boundary-layer separation, and turning angle. The data include surface pressure, heat transfer, and skin friction distributions as well as limited mean flowfield surveys in both the undisturbed and interaction regimes. The data were obtained for the purpose of validating computational models of these hypersonic interactions. Author

A93-23538* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECT OF SIDEWALL SUCTION ON FLOW IN TWO-DIMENSIONAL WIND TUNNELS
RICHARD W. BARNWELL (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 36-41. refs
Copyright

A closed-form analysis of flow in a two-dimensional subsonic wind tunnel that uses sidewall suction around the model to reduce sidewall boundary-layer effects is presented. The model problem that is treated involves a flat plate airfoil in a tunnel with a suction window shaped to permit an analytic solution. This solution shows that the lift coefficient depends explicitly on the porosity parameter of the suction window and implicitly on the suction pressure differential. For a given sidewall displacement thickness, the lift coefficient increases as the suction-window porosity decreases. Author

A93-23540
PERFORMANCE OF COMPRESSIBLE FLOW CODES AT LOW MACH NUMBERS
G. VOLPE (Grumman Corporate Research Center, Bethpage, NY) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 49-56. Previously cited in issue 18, p. 3054, Accession no. A91-43577 Research supported by DARPA and Cortana Corp refs
Copyright

A93-23541* National Aeronautics and Space Administration, Washington, DC.
NONLINEAR RELAXATION/QUASI-NEWTON ALGORITHM FOR THE COMPRESSIBLE NAVIER-STOKES EQUATIONS
JACK R. EDWARDS and D. S. MCRAE (North Carolina State Univ., Raleigh) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 57-60. Previously cited in issue 19, p. 3247, Accession no. A92-45510 Research supported by USAF and U.S. Navy refs
(Contract NAGW-1072)
Copyright

A93-23542
ADAPTIVE FINITE VOLUME UPWIND APPROACH ON MIXED QUADRILATERAL-TRIANGULAR MESHES
C. J. HWANG and S. J. WU (National Cheng Kung Univ., Tainan, Taiwan) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 61-67. refs
Copyright

An adaptive cell-vertex finite volume upwind approach on unstructured mixed quadrilateral-triangular meshes, where the quadrilaterals are directionally stretched in the flow regions having one-dimensional features, has been developed to solve the unsteady Euler equations. By using different combinations of interpolation variables, limiter functions, and numerical implementations of boundary conditions, a systematic study is made to understand the characteristics of the current approach. The isolated oblique shock problem, shock reflection at a wall, supersonic flow passing through a channel with a 4 percent circular arc bump, transonic flows around single- and two-element airfoils, as well as the shock propagation in a channel are investigated. It is concluded that the present solution procedure demonstrates good convergence performance and provides accurate and high-resolution results for the steady and unsteady inviscid flows. Author

A93-23545* National Aeronautics and Space Administration, Washington, DC.
ENGINEERING APPROACH TO THE PREDICTION OF SHOCK PATTERNS IN BOUNDED HIGH-SPEED FLOWS
D. J. AZEVEDO and CHING SHI LIU (New York State Univ., Amherst) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 83-90. refs
(Contract NAGW-966)
Copyright

A two-dimensional symmetric wedge configuration representative of a single high-speed intake in steady flow was investigated. The analysis presented here is intended as an engineering approach for estimating certain features of the internal shock system. The primary interest here is the prediction of the size and location of the almost-normal shock wave that develops when the leading-edge shocks intersect at angles above a certain critical value that is less than the wedge detachment angle. The almost-normal shock wave is frequently referred to as the 'Mach stem', Parametric studies enabled the sensitivity of the Mach stem height to various flowfield parameters to be examined, thus indicating how accurately these parameters must be measured in a given experiment. Results of these predictions were compared with those of a steady-flow experiment performed at nominal freestream Mach numbers from 2.8 to 5. The predicted stem heights were consistently lower than the mean experimental values, attributable both to experimental uncertainties and to certain simplifying assumptions used in the analysis. Modification of these assumptions to better represent the test environment improved the analytical results. Author

A93-23546
SHOCK/BOUNDARY-LAYER INTERACTION CONTROL WITH VORTEX GENERATORS AND PASSIVE CAVITY

D. C. MCCORMICK (United Technologies Research Center, East Hartford, CT) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 91-96. Previously cited in issue 07, p. 1010, Accession no. A92-22178 Research sponsored by U.S. Navy refs
Copyright

A93-23548* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MEASUREMENTS OF CIRCULATION AND VORTICITY IN THE LEADING-EDGE VORTEX OF A DELTA WING
K. D. VISSER and R. C. NELSON (Notre Dame Univ., IN) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 104-111. Research supported by Univ. of Notre Dame refs
(Contract NAG1-1156)
Copyright

The present cross-wire measurements of the flowfield above a 75-deg flat-plate delta wing have yielded distributions of velocity, axial vorticity, and circulation which exhibit strongly conical behavior upstream of the breakdown region and away from the apex and trailing edge regions. The conical character of these properties is most pronounced over the central portion of the planform, away from the apex and trailing-edge regions. This behavior is further documented by the roughly linear increase in vortex strength with distance from the apex over the forward area of the wing. O.C.

A93-23549
NEAR-FIELD BEHAVIOR OF A TIP VORTEX
A. SHEKARRIZ, T. C. FU, J. KATZ (Johns Hopkins Univ., Baltimore, MD), and T. T. HUANG (U.S. Navy, Naval Surface Warfare Center, Bethesda, MD) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 112-118. Previously cited in issue 23, p. 4007, Accession no. A91-53856 Research supported by U.S. Navy and DARPA refs
Copyright

A93-23552
NUMERICAL PREDICTION OF FLAP LOSSES IN A TRANSONIC WIND TUNNEL
NIDE G. C. R. FICO, JR. (Inst. de Aeronautica e Espaco, Sao Jose dos Campos, Brazil) and MARCOS A. ORTEGA (Inst. Tecnologico de Aeronautica, Sao Jose dos Campos, Brazil) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 133-139. refs
Copyright

Transonic wind-tunnel testing demands mass extraction at the test section. Part of the deviated flow entering the plenum chamber returns to the main stream through flaps that are located upstream of the high-speed diffuser. The main objectives of this paper are to predict values of the flap loss factor and to ascertain the influence of the returning secondary flow on the performance of the high-speed diffuser. As the ultimate goal is to calculate losses, modeling of the physical problem is performed by means of the Navier-Stokes equations. These equations are solved through the use of an implicit finite difference scheme due to Beam and Warming. The flowfield at the flap region, considering the flap as a separate element, is successfully simulated. As a result of the simulation, accurate value of the flap loss factor and of the high-speed diffuser inlet blockage are obtained. Finally, an application related to a practical loss calculation case is performed. It is observed that the flap re-entry flow exerts an important influence on the performance of the high-speed diffuser. Author

A93-23560
UNIT-REYNOLDS-NUMBER EFFECTS ON BOUNDARY-LAYER TRANSITION
KENNETH F. STETSON and ROGER L. KIMMEL (USAF, Wright Lab., Wright-Patterson AFB, OH) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 195, 196. refs

Attention is given to the problem posed by recent wind tunnel data which indicate that planar boundary layers have a greater variation of transition Reynolds-number with unit Reynolds number than conical boundary layers. Attention is given to the testimony of hot-wire anemometry experiments as to the details of major disturbances found in planar and conical laminar boundary layers. Numerical results for the laminar planar boundary layer have also indicated that second-mode disturbances should also be the major disturbances in the planar boundary layer. O.C.

A93-23563
SHOCK OSCILLATION IN TWO-DIMENSIONAL, INVISCID, UNSTEADY CHANNEL FLOW
SHEN-MIN LIANG and CHOU-JIU TSAI (National Cheng Kung Univ., Tainan, Taiwan) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 200-203. refs
(Contract NSC-80-0401-E006-39)
Copyright

An effort is made to compare the difference of forced shock oscillations between 2D and 1D channel flows with different channel-expansion ratio values. Attention is given to the parameter tau, defined as the difference between the channel exit area and the throat area, divided by the throat area; for large values of tau, numerical methods are required. The influence of amplitude and frequency on the shock movement is also explored. O.C.

A93-23565
SUBHARMONIC AND HARMONIC FORCED RESPONSE OF THE WAKE OF A CIRCULAR CYLINDER
MOHAMMAD J. KHAN and ANWAR AHMED (Texas A & M Univ., College Station) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 208, 209. refs
Copyright

Measurements have been conducted of the forced response of the wake of a circular cylinder with an oscillating splitter plate installed near the leading-edge attachment line. This configuration can be used to modify the wake through subharmonic interaction; at frequencies higher than the natural shedding frequency, the configuration can result in a reduction of wake width and bluff body drag. The control parameters for bluff body wake modification are identified to be the plate oscillation frequency and amplitude. O.C.

N93-15889# Air Force Inst. of Tech., Wright-Patterson AFB, OH. Foreign Aerospace Science and Technology Center.
TRANSITION INDUCED NORMAL FORCES AND THEIR EFFECTS ON THE AERODYNAMIC CHARACTERISTICS OF SLENDER SHARP CONES
LOU HONGTIAN 5 Mar. 1992 34 p Transl. into ENGLISH from Yuhang Xuebao (China), no. 3, 1989 p 54-64
(AD-A256802; FASTC-ID(RS)T-0790-91) Avail: CASI HC A03/MF A01

When there is boundary layers transition, whether or not one has the appearance of induced normal aerodynamic loads is a very significant question. This article introduces static and dynamic aerodynamic force experiments which were completed in hypersonic wind tunnels. They experimentally verify the existence of this type of load in normal directions. It is created by the asymmetrical nature of boundary layer transitions. In conjunction with this, they have clear and regular influences on the aerodynamic characteristics of long slender cones. GRA

N93-15920# Naval Postgraduate School, Monterey, CA.
COMPUTATIONAL INVESTIGATIONS OF A NACA 0012 AIRFOIL IN LOW REYNOLDS NUMBER FLOWS M.S. Thesis
LISA M. NOWAK Sep. 1992 147 p
(AD-A257300) Avail: CASI HC A07/MF A02

A steady flow analysis is conducted for a NACA 0012 airfoil in low Reynolds number flows ranging from 540,000 to 1,000,000. Emphasis is placed on prediction and location of the separation bubble. Computational methods include the direct boundary layer method, the viscous-inviscid interaction method, and the time-averaged Navier-Stokes method. Characteristic trends in skin friction coefficient, displacement thickness, and boundary layer velocity profiles with increasing angle of attack are observed. Computational results are compared to each other and to experimental photographs visualizing the density flowfield using

Point Diffraction Interferometry. Both the viscous-inviscid method and the Navier-Stokes method failed to accurately represent leading edge separation bubbles. The direct boundary layer method, usually considered of very limited usefulness due to a singularity in the underlying equations at separation, is shown to exhibit unexpected recovery behavior for small amounts of separation. Furthermore, the results near the leading edge, where separation bubbles were computed, were validated by the experiment. GRA

N93-16157# Naval Postgraduate School, Monterey, CA.
QUANTITATIVE-FORCE MEASUREMENTS OF PNEUMATIC CONTROL ON A WING/STRAKE MODEL M.S. Thesis
JAMES G. WILLSON Sep. 1992 119 p
(AD-A257343) Avail: CASI HC A06/MF A02

A low speed wind tunnel study to quantitatively measure the lift and drag effects of pneumatically controlling a leading edge vortex generated by a half-span, generic fighter wing model was conducted. The study measured the added lift and drag upon the model, throughout a range of angles of attack, utilizing blowing tubes of different geometry and orientations. The effects of blowing upon the high pressure side of the strake were also investigated. Results showed that the effects of blowing were limited to changes in lift with no apparent changes in drag. Blowing appeared to reattach the flow during the initial stages of wing stall. Blowing increased lift by a maximum of 3.75 pct. at angles of attack greater than 25 degs. The effects of blowing appeared oscillatory with respect to angle of attack. Blowing rates were varied from Cmu = 0.0 to 0.0035 in an attempt to determine an optimum. It was found that changes in blowing rates had little effect upon delta CL. GRA

N93-16210# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.
EXPERIMENTAL AND NUMERICAL INVESTIGATION OF VORTEX FLOW OVER A 76/60-DEG DOUBLE-DELTA WING
J. E. J. MASELAND and N. G. VERHAGGEN Apr. 1992 99 p
(LR-680; ETN-92-92875) Avail: CASI HC A05/MF A02

A low speed wind tunnel investigation of the characteristics of the vortex flow over a 76/60 deg double delta wing at a constant angle of attack of 20 deg is described. The objective of the investigation was to support the development and validation of numerical codes by generating experimental data in the vortex interaction downstream of the strake-wing leading edge kink of a double delta wing. Detailed flow field surveys and surface pressure measurements provide data on the pressure and velocity distribution at various chordwide stations. The experimental data is compared with numerical solutions of a free vortex sheet and a Navier-Stokes code. ESA

N93-16467# Manchester Univ. (England). Aeronautical Engineering Group.
HYPERSONIC FLOWS INCLUDING REAL GAS EFFECTS Ph.D. Thesis
S. SHAHPAR and I. M. HALL 1991 612 p
(AERO-REPT-9112; ETN-92-92778) Avail: CASI HC A99/MF A06

The development of an overlapping grid technique to allow mesh configurations to be designed for local elements of a complicated three dimensional shape, the addition of a global iteration procedure for solutions of the Parabolized Navier-Stokes (PNS) equations, and the use of TVD schemes to solve flows at high temperatures where real gas effets are important are reported. Both equilibrium and nonequilibrium flows are considered. Overlapping grids were used on two specific problems which model particular aspects of a reentry vehicle: for the inviscid, hypersonic, perfect gas flow over a double ellipse, modeling a forebody canopy junction, and for a similar flow over a highly swept cylinder emerging from a flat plate, similar to the wing root junction of Hermes. An efficient implicit noninteractive PNS code was developed and validated through a simple test case. However, a single pass PNS code is only suitable where the viscous inviscid interaction is weak. The use of a global interation procedure for solving strong interaction problems was demonstrated for a family of compression corners in hypersonic flow. Using an equilibrium air model some hypersonic blunt body flows are computed and the results were consistent with similar ones obtained by other authors. Nonequilibrium flows introduce stiffness problems which were dealt with by designing a point implicit TVD method. The algorithm was successfully applied to configurations which are shortly to be tested in a shock tunnel. Validation of the latter code will be made as soon as the experimental results are available. ESA

N93-16470# Manchester Univ. (England). Aeronautical Engineering Group.
COMPUTATIONAL STUDY OF REAL GAS EFFECTS IN HIGH SPEED HIGH TEMPERATURE FLOW, VOLUME 2 Final Report, 1991
S. SHAHPAR, I. M. HALL, and D. I. A. POLL 1992 112 p
(Contract SMD097865)
(AERO-REPT-9203-VOL-2; ETN-92-92780) Avail: CASI HC A06/MF A02

The computational results and the development of programs on real gas effects are presented. Nonequilibrium chemically reacting inviscid flow programs are described for high enthalpy shock tunnels as well as high speed atmospheric reentry flows. Initially the programs were intended to be research codes; they were made as user friendly as possible. The high speed chemical nonequilibrium calculations were performed using the computer codes CYLO2 and CYLAIR. The computations were made on a VP-1100 computer. The computational results show that the present total variation diminishing scheme is satisfactory for simulation of low hypersonic flows with real gas effects. There is an uncertainty of about 8 percent on the stagnation temperature for free stream Mach numbers of the order of 20 when compared with published results. In the light of the obtained results, more work to understand the effects of real gas nonequilibrium chemistry is recommended. ESA

N93-16508 California Inst. of Tech., Pasadena.
MIXING AND REACTION IN THE SUBSONIC 2-D TURBULENT FREE SHEAR LAYER Ph.D. Thesis
CLIFFORD EUGENE FRIELER 1992 259 p
Avail: Univ. Microfilms Order No. DA9232175

The amount of mixed fluid is estimated by performing 'flip' experiments and sensing the heat released due to reactions between H2, F2 and NO carried in inert diluent gases. The effects of density ratio, chemical kinetics and Reynolds number were investigated using this approach which avoids the usual resolution limitations. Experiments covering a factor of 30 range in density ratio are presented. Several aspects of the mixing process, such as the distribution of mixed fluid, appear insensitive to density ratio. The integral amount of mixed fluid varies less than 6 percent. This insensitivity contrasts with that of the profiles of mixed fluid composition. While having similar shapes, the composition profile offset depends strongly upon the density ratio. Power spectral densities of the temperature fluctuations are presented and are found to collapse upon normalization with the adiabatic flame temperature and large-structure passage frequency. Probability density functions of composition are presented and indicate that for all density ratios, a predominant composition of the mixed fluid exists within the turbulence. The initial work of Mungal and Frieler on the effects of chemical kinetics on the formation of product in the 2-D mixing layer has been greatly expanded. Measurements have been extended to include a wider range of NO concentrations and have been performed for two other stoichiometries. Results indicate that the simple model used to explain the effects of reaction kinetics in Mungal and Frieler may only be suited for cases with extreme stoichiometry (very high or very low). It has also been found that more product is formed when F2 is the rich reactant than when H2 is the rich reactant. This dependence upon molecular character questions both the experimental technique and theory and modeling of this reacting flow, and stems from a coupling of the effects of differing diffusivity and chemical kinetics. Numerical calculations based on simplified flow models are reported that demonstrate this coupling. The effects of Reynolds number are also examined. Evidence of the

remnants of the initial roll-up and mixing transition is seen for Reynolds number as large as 30,000. Resonance with the acoustic mode of the apparatus affects results for Reynolds numbers up to 60,000. Natural transition of the high and low-speed boundary layer at the mixing-layer inlet affect the high Reynolds number data. In spite of these qualifications, the amount of mixed fluid is nearly constant. Over the range of Reynolds numbers 10,000 to 200,000 it varies by less than 12 percent and displays no asymptotic decline. Dissert. Abstr.

N93-16522 ESDU International Ltd., London (England).
MAXIMUM LIFT OF WINGS WITH LEADING-EDGE DEVICES AND TRAILING-EDGE FLAPS DEPLOYED
Nov. 1992 24 p
(ISSN 0141-397X)
(ESDU-92031; ISBN-0-85679-837-1) Avail: ESDU

ESDU 92031 provides an empirical method for straight-tapered wings with leading-edge devices deployed, with or without the deployment of trailing-edge flaps, at freestream Mach numbers up to 0.25. The maximum lift of the wing with high-lift devices retracted is first calculated (by the method of ESDU 89034 which uses predictions for the maximum lift of the aerofoil from ESDU 84026). ESDU 92031 then predicts the increment in maximum lift due to deploying a leading-edge device by applying the increment in two-dimensional flow obtained from ESDU 85033 to the most highly-loaded section with allowances for the effects of wing aspect ratio, taper and sweep, and for the effects of part-span (the device must extend to the wing tip) if appropriate. In the absence of a deployed leading edge device, the deployment of a trailing-edge flap yields an increment in maximum lift, obtained from ESDU 91014, which is reduced due to mutual interference when the devices are deployed together by a decrement obtained from ESDU 92031. The method applies for wing aspect ratios of 3 to 9 and leading-edge sweeps up to 50 degrees with plain, split, or single- or multiple-slotted trailing edge flaps, and leading-edge flaps, slats, or vented or unvented Kruger flaps. It predicts the increment in maximum lift coefficient due to leading-edge devices, alone or in combination with trailing-edge flaps, to within 0.1. A similar accuracy applies for the overall maximum lift coefficient of the wing with deployed high lift devices. Two worked examples illustrate the use of the method. ESDU

N93-16596*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A REALIZABLE REYNOLDS STRESS ALGEBRAIC EQUATION MODEL
TSAN-HSING SHIH, JIANG ZHU, and JOHN L. LUMLEY (Cornell Univ., Ithaca, NY.) Jan. 1993 36 p Presented at the Ninth Symposium on Turbulence Shear Flows, Kyoto, Japan, 10-18 Aug. 1993
(Contract NASA ORDER C-99066-G; RTOP 505-62-21)
(NASA-TM-105993; ICOMP-92-27; E-7525; NAS 1.15:105993; CMOTT-92-14) Avail: CASI HC A03/MF A01

The invariance theory in continuum mechanics is applied to analyze Reynolds stresses in high Reynolds number turbulent flows. The analysis leads to a turbulent constitutive relation that relates the Reynolds stresses to the mean velocity gradients in a more general form in which the classical isotropic eddy viscosity model is just the linear approximation of the general form. On the basis of realizability analysis, a set of model coefficients are obtained which are functions of the time scale ratios of the turbulence to the mean strain rate and the mean rotation rate. The coefficients will ensure the positivity of each component of the mean rotation rate. These coefficients will ensure the positivity of each component of the turbulent kinetic energy - realizability that most existing turbulence models fail to satisfy. Separated flows over backward-facing step configurations are taken as applications. The calculations are performed with a conservative finite-volume method. Grid-independent and numerical diffusion-free solutions are obtained by using differencing schemes of second-order accuracy on sufficiently fine grids. The calculated results are compared in detail with the experimental data for both mean and turbulent quantities. The comparison shows that the present proposal significantly improves the predictive capability of K-epsilon based two equation models. In addition, the proposed model is able to simulate rotational homogeneous shear flows with large rotation rates which all conventional eddy viscosity models fail to simulate. Author

N93-16625*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EFFECT OF A ROTATING PROPELLER ON THE SEPARATION ANGLE OF ATTACK AND DISTORTION IN DUCTED PROPELLER INLETS
D. R. BOLDMAN, C. IEK, D. P. HWANG, M. LARKIN (Pratt and Whitney Aircraft, East Hartford, CT.), and P. SCHWEIGER (Pratt and Whitney Aircraft, East Hartford, CT.) Jan. 1993 16 p Presented at the 31st Aerospace Sciences Meeting and Exhibit, Reno, NV, 11-14 Jan. 1993; Sponsored by AIAA
(Contract RTOP 505-03-10)
(NASA-TM-105935; E-7451; NAS 1.15:105935; AIAA PAPER 93-0017) Avail: CASI HC A03/MF A01

The present study represents an extension of an earlier wind tunnel experiment performed with the P&W 17-in. Advanced Ducted Propeller (ADP) Simulator operating at Mach 0.2. In order to study the effects of a rotating propeller on the inlet flow, data were obtained in the UTRC 10- by 15-Foot Large Subsonic Wind Tunnel with the same hardware and instrumentation, but with the propeller removed. These new tests were performed over a range of flow rates which duplicated flow rates in the powered simulator program. The flow through the inlet was provided by a remotely located vacuum source. A comparison of the results of this flow-through study with the previous data from the powered simulator indicated that in the conventional inlet the propeller produced an increase in the separation angle of attack between 4.0 deg at a specific flow of 22.4 lb/sec-sq ft to 2.7 deg at a higher specific flow of 33.8 lb/sec-sq ft. A similar effect on separation angle of attack was obtained by using stationary blockage rather than a propeller. Author

N93-16627*# Institute for Computer Applications in Science and Engineering, Hampton, VA.
VORTEX BREAKDOWN INCIPIENCE: THEORETICAL CONSIDERATIONS
STANLEY A. BERGER and GORDON ERLEBACHER Washington Nov. 1992 27 p Submitted for publication
(Contract NAS1-18605; NAS1-19480; RTOP 505-90-52-01)
(NASA-CR-189734; ICASE-92-63; NAS 1.26:189734) Avail: CASI HC A03/MF A01

The sensitivity of the onset and the location of vortex breakdowns in concentrated vortex cores, and the pronounced tendency of the breakdowns to migrate upstream have been characteristic observations of experimental investigations; they have also been features of numerical simulations and led to questions about the validity of these simulations. This behavior seems to be inconsistent with the strong time-like axial evolution of the flow, as expressed explicitly, for example, by the quasi-cylindrical approximate equations for this flow. An order-of-magnitude analysis of the equations of motion near breakdown leads to a modified set of governing equations, analysis of which demonstrates that the interplay between radial inertial, pressure, and viscous forces gives an elliptic character to these concentrated swirling flows. Analytical, asymptotic, and numerical solutions of a simplified non-linear equation are presented; these qualitatively exhibit the features of vortex onset and location noted above. Author

N93-16634 ESDU International Ltd., London (England).
DRAG DUE TO GAPS ROUND UNDEFLECTED TRAILING-EDGE CONTROLS AND FLAPS AT SUBSONIC SPEEDS Abstract Only
Nov. 1992 12 p
(ISSN 0141-397X)
(ESDU-92039; ISBN-0-85679-847-9) Avail: ESDU

ESDU 92039 discusses the qualitative effects of control gaps on wing aerodynamic characteristics, explains the sources of drag,

and considers the benefits of sealing. The effects of wing section and control section profile mismatch on control gap drag are also considered. The limited data in the literature are used to develop empirical prediction methods for the drag due to unsealed spanwise gaps while for unsealed chordwise gaps, for which the data are too few to be correlated, guidelines on upper limits to drag are given. Methods of allowing for the effect of sealing are suggested in both cases. The data apply to controls or flaps with ratios of control or flap chord to wing chord of 0.1 to 0.3 at the control or flap mid span and hinge lines swept by up to 30 degrees. The methods apply to wing lift coefficients between 0 and 0.6 and are independent of Mach number (provided the flow is everywhere subsonic) and of Reynolds number for gap depth to width ratios equal to or exceeding 3. The accuracy of the methods is assessed, and sketches compare experimental values with prediction. A worked example illustrates the use of the methods and highlights the need for gap sealing. Author

N93-16638 ESDU International Ltd., London (England).
CONTRIBUTION OF VENTRAL FINS TO SIDEFORCE AND YAWING MOMENT DERIVATIVES DUE TO SIDESLIP AT LOW ANGLE OF ATTACK Abstract Only
Nov. 1992 37 p
(ISSN 0141-397X)
(ESDU-92029; ISBN-0-85679-835-5) Avail: ESDU

ESDU 92029 applies at subsonic speeds to configurations with a body- or fin-mounted tailplane and a main fin in the plane of symmetry for angles of attack and sideslip up to 5 and 4 degrees respectively. The method is an empirical modification of long-standing theoretical calculations that allow for the interference of body, wing, tailplane and main fin. The sideforce is obtained from the lift-curve slope (from ESDU 70011 at subsonic speeds or 70012 at supersonic speeds, or from slender body theory for low aspect ratios, empirically modified) factored by the appropriate interference factor. The yawing moment derivative is calculated by taking the point of action of the sideforce at quarter- or mid-point of a chord 0.4 of the heights of the fin from the root; more precise methods resulted in little improvement in accuracy and so did not warrant the greater complexity. Sketches comparing predictions with experimental data extracted from the literature show the accuracy of both derivatives to be within 0.15 plus 15 percent. The ranges of geometry and Mach number for the experimental results are tabulated. Author

N93-16704*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXPERIMENTAL INVESTIGATION OF AN EJECTOR-POWERED FREE-JET FACILITY
MARY JO LONG Jul. 1992 15 p Presented at the 28th Joint Propulsion Conference, Nashville, TN, 6-8 Jul. 1992; sponsored by AIAA, ASME, SAE, and ASEE Previously announced in IAA as A92-54058
(Contract RTOP 537-02-23)
(NASA-TM-105868; E-7331; NAS 1.15:105868; AIAA PAPER 92-3569) Avail: CASI HC A03/MF A01

NASA Lewis Research Center's (LeRC) newly developed Nozzle Acoustic Test Rig (NATR) is a large free-jet test facility powered by an ejector system. In order to assess the pumping performance of this ejector concept and determine its sensitivity to various design parameters, a 1/5-scale model of the NATR was built and tested prior to the operation of the actual facility. This paper discusses the results of the 1/5-scale model tests and compares them with the findings from the full-scale tests. Author

N93-16710*# Vigyan Research Associates, Inc., Hampton, VA.
MODIFICATIONS TO LANGLEY 0.3-M TCT ADAPTIVE WALL SOFTWARE FOR HEAVY GAS TEST MEDIUM, PHASE 1 STUDIES
A. V. MURTHY Dec. 1992 42 p
(Contract NAS1-18585; RTOP 505-59-86-02)
(NASA-CR-189736; NAS 1.26:189736) Avail: CASI HC A03/MF A01

The scheme for two-dimensional wall adaptation with sulfur hexafluoride (SF6) as test gas in the NASA Langley Research Center 0.3-m Transonic Cryogenic Tunnel (0.3-m TCT) is presented. A unified version of the wall adaptation software has been developed to function in a dual gas operation mode (nitrogen or SF6). The feature of ideal gas calculations for nitrogen operation is retained. For SF6 operation, real gas properties have been computed using the departure function technique. Installation of the software on the 0.3-m TCT ModComp-A computer and preliminary validation with nitrogen operation were found to be satisfactory. Further validation and improvements to the software will be undertaken when the 0.3-m TCT is ready for operation with SF6 gas. Author

N93-16765*# Illinois Univ., Chicago. Dept. of Mechanical Engineering.
INTERFEROMETRIC RECONSTRUCTION OF THREE-DIMENSIONAL HIGH-SPEED AERODYNAMIC FLOWS
SOYOUNG STEPHEN CHA *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 91-92 Sep. 1992
Avail: CASI HC A01/MF A03

Holographic interferometry can be a very useful diagnostic tool in high-speed aerodynamic testing. During this summer research period, various possible approaches for accurately reconstructing three-dimensional flows from limited data were examined. The approach based on the combination of the following three techniques appears to be promising: (1) Continuous Local Basis Function Method - this computational tomographic method has a power to accurately reconstruct continuous regions and is appropriate from well-conditioned to moderately limited data; (2) Variable Basis Method - this computational tomographic method provides accuracy near discontinuities, i.e., shock regions, and is appropriate from moderately-limited to severely-limited data; and (3) Complementary Field Method - this is a general iterative reconstructor that can be coupled with any computational tomographic techniques. Mathematically, it can be shown that this method can provide better accuracy than the direct reconstruction as in a conventional approach. Our numerical simulation of experiments demonstrated improved reconstruction results even when these techniques were individually tested. Author

N93-16768*# Missouri Univ., Rolla. Dept. of Mechanical and Aerospace Engineering.
PRELIMINARY EFFORTS TOWARD DEVELOPMENT OF DATA HANDLING AND ANALYSIS SOFTWARE FOR UNSTEADY FLOW MEASUREMENTS: AN APPLICATION FOR AEROELASTIC TRANSONIC FLOW CONFIGURATIONS
FATHI FINAISH *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 99-105 Sep. 1992
Avail: CASI HC A02/MF A03

A few years ago the Structural Dynamics Division at LaRC started ambitious experimental research efforts known as the Benchmark Models Program. The primary objective of this program was to provide experimental data that may serve as a calibration source for computational fluid dynamics (CFD) efforts that deal with aeroelastic unsteady flow configurations. It also focuses on the understanding of complex flow phenomenon associated with unsteady flow developments. The overall plan for the program has been described by Bennett, including a presentation of initial test results of flutter of a rigid wing mounted on flexible supports. An example of a test model employed to measure the dynamic response along with corresponding pressure distributions is shown. This model incorporates eighty pressure transducers distributed along two spanwise stations. In addition, the models are equipped with four accelerometers and two strain gages. The data handling system for the Benchmark Model Program is under development. Several interactive computer routines designed for the user interface, dynamic memory allocation, unsteady flow measurements data extraction, and further data processing were developed. To present a few examples of measured data, the unsteady pressure distributions and the wing model dynamic response were plotted. Author

N93-16770*# Wilkes Coll., Wilkes-Barre, PA. Dept. of Mechanical Engineering.
WIND TUNNEL SEEDING PARTICLES FOR LASER VELOCIMETER
ANTHONY GHORIESHI *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 110-115 Sep. 1992
Avail: CASI HC A02/MF A03

The design of an optimal air foil has been a major challenge for aerospace industries. The main objective is to reduce the drag force while increasing the lift force in various environmental air conditions. Experimental verification of theoretical and computational results is a crucial part of the analysis because of errors buried in the solutions, due to the assumptions made in theoretical work. Experimental studies are an integral part of a good design procedure; however, empirical data are not always error free due to environmental obstacles or poor execution, etc. The reduction of errors in empirical data is a major challenge in wind tunnel testing. One of the recent advances of particular interest is the use of a non-intrusive measurement technique known as laser velocimetry (LV) which allows for obtaining quantitative flow data without introducing flow disturbing probes. The laser velocimeter technique is based on measurement of scattered light by the particles present in the flow but not the velocity of the flow. Therefore, for an accurate flow velocity measurement with laser velocimeters, two criterion are investigated: (1) how well the particles track the local flow field, and (2) the requirement of light scattering efficiency to obtain signals with the LV. In order to demonstrate the concept of predicting the flow velocity by velocity measurement of particle seeding, the theoretical velocity of the gas flow is computed and compared with experimentally obtained velocity of particle seeding. L.R.R.

N93-16784*# Texas A&M Univ., College Station. Dept. of Aerospace Engineering.
DIGITAL DATA ACQUISITION AND PRELIMINARY INSTRUMENTATION STUDY FOR THE F-16 LAMINAR FLOW CONTROL VEHICLE
CYRUS OSTOWARI *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 157-163 Sep. 1992
Avail: CASI HC A02/MF A03

Preliminary studies have shown that maintenance of laminar flow through active boundary-layer control is viable. Current research activity at NASA Langley and NASA Dryden is utilizing the F-16XL-1 research vehicle fitted with a laminar-flow suction glove that is connected to a vacuum manifold in order to create and control laminar flow at supersonic flight speeds. This experimental program has been designed to establish the feasibility of obtaining laminar flow at supersonic speeds with highly swept wing and to provide data for computational fluid dynamics (CFD) code calibration. Flight experiments conducted as supersonic speeds have indicated that it is possible to achieve laminar flow under controlled suction at flight Mach numbers greater than 1. Currently this glove is fitted with a series of pressure belts and flush mounted hot film sensors for the purpose of determining the pressure distributions and the extent of laminar flow region past the stagnation point. The present mode of data acquisition relies on out-dated on board multi-channel FM analogue tape recorder system. At the end of each flight, the analogue data is digitized through a long laborious process and then analyzed. It is proposed to replace this outdated system with an on board state-of-the-art digital data acquisition system capable of a through put rate of up to 1 MegaHertz. The purpose of this study was three-fold: (1) to develop a simple algorithm for acquiring data via 2 analogue-to-digital convertor boards simultaneously (total of 32 channels); (2) to interface hot-film/wire anemometry instrumentation with a PCAT type computer; and (3) to characterize the frequency response of a flush mounted film sensor. A brief description of each of the above tasks along with recommendations are given. Author

N93-16787*# Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics.
BOUNDARY-LAYER MEASUREMENTS ON A HIGH REYNOLDS NUMBER THREE-ELEMENT AIRFOIL
GREGORY V. SELBY *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 171-172 Sep. 1992
Avail: CASI HC A01/MF A03

An experimental investigation is being conducted to evaluate the boundary layer associated with a two-dimensional three-element single-flap airfoil at high Reynolds numbers. The present measurements are being made in the Langley Low-Turbulence (centerline turbulence intensity level is 0.034 percent at a Mach number of 0.2 and a total pressure of 60 psia) Pressure Tunnel (LTPT). The LTPT is a closed-circuit wind tunnel with a test section which is 3 ft wide, 7.5 ft high, and 7.5 ft long. Operating total pressure for the LTPT varies from 10 atmospheres to near-vacuum conditions. Tests are being conducted at a Mach number of 0.2 and Reynolds numbers (based on chord length) of 5, 9, and 16 million. Measurements include boundary-layer velocity surveys at several chordwise locations and surface skin-friction measurements using Preston tubes. Author

N93-16797*# California State Univ., Los Angeles. Dept. of Mechanical Engineering.
NAVIER-STOKES CALCULATION OF TRANSONIC FLOW PAST THE NTF 65-DEG DELTA WING
CHIVEY WU *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 191-199 Sep. 1992
Avail: CASI HC A02/MF A03

Viscous flow past a wind tunnel model of a 65-degree swept angle Delta wing at transonic speeds is being studied. The model was tested in the 8-foot cryogenic transonic wind tunnel at the National Transonic Facility. Aerodynamic forces and wing surface pressure data were obtained at various angles of attack, Mach numbers, and Reynold's numbers for four different leading edges of the wing. The objectives of the present investigation are: (1) to perform numerical modeling of the flow around the wing; (2) to validate the experimental data with a Navier-Stokes computational fluid dynamics code and vice versa; (3) to investigate the effects of the sting mount of the wing; (4) to evaluate the effects of leading edge radius on the flow; and (5) to explain the Reynold's number effect as indicated by the test data. Several computer programs were developed to define the surfaces of the wing, the four leading edges, and the sting mount. Based on these geometric databases, the surface grids of a single-block computational domain was generated interactively on the IRIS workstation using the GRIDGEN2D module of GRIDGEN. To refine the grids and to avoid excessive loss of grid points due to collapsed edges, a 9-block computational domain containing approximately 750,000 grid points was developed with the GRIDBLOCK module to replace the single-block grid. Author

N93-16940*# Vigyan Research Associates, Inc., Hampton, VA.
DESIGN OPTIMIZATION OF NATURAL LAMINAR FLOW BODIES IN COMPRESSIBLE FLOW
SIMHA S. DODBELE Washington Dec. 1992 20 p
(Contract NAS1-18585; RTOP 505-59-10-02)
(NASA-CR-4478; NAS 1.26:4478) Avail: CASI HC A03/MF A01

An optimization method has been developed to design axisymmetric body shapes such as fuselages, nacelles, and external fuel tanks with increased transition Reynolds numbers in subsonic compressible flow. The new design method involves a constraint minimization procedure coupled with analysis of the inviscid and viscous flow regions and linear stability analysis of the compressible boundary-layer. In order to reduce the computer time, Granville's transition criterion is used to predict boundary-layer transition and to calculate the gradients of the objective function, and linear stability theory coupled with the e(exp n)-method is used to calculate the objective function at the end of each design iteration. Use of a method to design an axisymmetric body with extensive natural laminar flow is illustrated through the design of

a tiptank of a business jet. For the original tiptank, boundary layer transition is predicted to occur at a transition Reynolds number of 6.04 x 10(exp 6). For the designed body shape, a transition Reynolds number of 7.22 x 10(exp 6) is predicted using compressible linear stability theory coupled with the e(exp n)-method. Author

N93-16942*# Scientific Research Associates, Inc., Glastonbury, CT.

TWO- AND THREE-DIMENSIONAL BLADE VORTEX INTERACTIONS

F. DAVOUDZADEH, N.-S LIU, W. R. BRILEY, R. C. BUGGELN, and S. J. SHAMROTH Aug. 1990 222 p Original contains color illustrations

(Contract NAS2-12635)

(NASA-CR-177567; A-90275; NAS 1.26:177567) Avail: CASI HC A10/MF A03; 60 functional color pages

A three-dimensional time dependent Navier-Stokes analysis was applied to the rotor blade vortex interaction (BVI) problem. The numerical procedure is an iterative implicit procedure using three point central differences to represent spatial derivatives. A series of calculations were made to determine the time steps, pseudo-time steps, iterations, artificial dissipation level, etc. required to maintain a nondissipative vortex. Results show the chosen method to have excellent non-dissipative properties provided the correct parameters are chosen. This study was used to set parameters for both two- and three-dimensional blade vortex interaction studies. The two-dimensional study considered the interaction between a vortex and a NACA0012 airfoil. The results showed the detailed physics during the interaction including the pressure pulse propagating from the blade. The simulated flow physics was qualitatively similar to that experimentally observed. The 2-D BVI phenomena is the result of the buildup and violent collapse of the shock waves and local supersonic pockets on the blade surfaces. The resulting pressure pulse build-up appears to be centered at the blade leading edge. The three-dimensional interaction study considered the case of a vortex at 20 deg incidence to the blade leading edge. Although the qualitative results were similar to that of the two-dimensional interaction, details clearly showed the three-dimensional nature of the interaction process. Author

N93-17542# Institut de Mecanique des Fluides de Lille (France).

EFFECT OF REYNOLDS NUMBER ON THE STANDARDS OF A SIMPLIFIED ANEMOCLINOMETRIC PROBE [EFFET DU REYNOLDS SUR L'ETALONNAGE D'UNE SONDE ANEMOCLINOMETRIQUE SIMPLIFIEE]

A. OTTAVY and P. BAILLEUX 4 Sep. 1991 33 p In FRENCH

(Contract DRET-89-003-17)

(IMFL-91-31; ETN-92-92556) Avail: CASI HC A03/MF A01

The effect of Reynolds number on the standard characteristics of a flow velocity measuring probe is investigated. An anemoclinometer is a system able to measure velocity flow vector from pressure flow data. The aim is to verify whether each different flow velocity should be associated to a different standard or not. The calculations were performed for angles between -50 to +50 deg. The results are compared to those obtained from a spherical probe. In order to evaluate the accuracy, dispersion error calculations were peformed at small angles. Similar results were obtained by using a classic calculation method. The maximal deviation calculated was of about 1 deg, for all the different Reynolds numbers used. The results show that the probe can perform measurements in variable velocity flows, in a complex flow and large angular fields. ESA

N93-17543# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Hubschrauber und Flugzeuge.

HOT EXPERIMENTAL TECHNIQUE: A NEW REQUIREMENT OF AEROTHERMODYNAMICS

E. H. HIRSCHEL 9 Mar. 1992 18 p Presented at NATO Advanced Research Workshop on New Trends in Instrumentation for Hypersonic Research, Le Fauga, Italy, 27 Apr. - 1 May 1992

(MBB-FE-202-S-PUB-480; ETN-92-92574) Copyright Avail: CASI HC A03/MF A01

The flow past hypersonic vehicles causes large heat loads on the vehicle surface. It is shown that the heat loads and the flow properties are strongly coupled if radiation cooling is employed. Similar phenomena occur in interacting flows and in nonequilibrium viscous flows. The large demands on ground facility simulation of hypersonic flows make new methods in experimental work necessary. A hot experimental technique, each for three different typical measurement problems, is proposed. Details of the technique, regarding the tunnel type, model, and measurement techniques are discussed. A stepwise approach to the involved problems is suggested. ESA

N93-17568# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany).

CURRENT EUROPEAN ROTORCRAFT RESEARCH ACTIVITIES ON DEVELOPMENT OF ADVANCED CFD METHODS FOR THE DESIGN OF ROTOR BLADES (BRITE/EURAM DACRO PROJECT)

G. POLZ 1991 11 p Presented at 17th European Rotorcraft Forum, Berlin, Germany, 24-27 Sep. 1991; sponsored by DGLR Previously announced in IAA as A92-56332

(MBB-UD-0601-91-PUB; ETN-92-92578) Avail: CASI HC A03/MF A01

Work performed up to now in the BRITE/EURAM Pilot Phase project DACRO is described. Focus is on the development and validation of new Computational Fluid Dynamics (CFD) codes for application to the aerodynamic environment of helicopter rotor blades. Additional tasks are the reviewing of the current computational methods, the definitions of possible improvements, and the selection of appropriate data bases for code validation. The theories applied by the partners are: transonic small perturbation theory; unsteady full potential theory; and Euler methods. Based on these theories, the development of new codes and the improvement of existing codes was undertaken by the partners. Methods in use are described and the progress achieved up to now is demonstrated. ESA

N93-17677# Naval Postgraduate School, Monterey, CA.

A MULTI-FACETED ENGINEERING STUDY OF AERODYNAMIC ERRORS OF THE SERVICE AIRCRAFT INSTRUMENTATION PACKAGE (SAIP) M.S. Thesis

JOSEPH W. RIXEY Sep. 1992 119 p

(AD-A258059) Avail: CASI HC A06/MF A02

The general objectives of this research are to investigate, identify, and quantify the aerodynamic sources of altitude determination errors of the U.S. Navy's Service Aircraft Instrumentation Package (SAIP) and to make recommendations to remedy these errors. This multi-faceted study includes aero-panel methods, computational fluid dynamics (CFD), wind tunnel testing, and flight test evaluations. The Airflow Sensor Assembly (ASA), a device similar to a calibrated pitot static tube, was intended to meet the SAIP's required specifications for altitude determination. However, the ASA is housed in the five inch diameter body of the SAIP and mounted on a variety of host aircraft. The over-pressure generated by the SAIP body as well as the wing/pylon system engulf the static pressure ports creating altitude errors well out of performance limits. This over-pressure associated with these bodies was apparently not accounted for during design and acquisition and extensive modifications will be needed to offset or eliminate their effects. GRA

N93-17756# Naval Postgraduate School, Monterey, CA.

FLOWFIELD COMPUTATIONS OVER THE SPACE SHUTTLE ORBITER WITH A PROPOSED CANARD AT A MACH NUMBER OF 5.8 AND 50 DEG ANGLE OF ATTACK M.S. Thesis

WILLIAM H. REUTER Jun. 1993 47 p

(AD-A258058) Avail: CASI HC A03/MF A01

Advances in computational fluid dynamics (CFD) capabilities in the last decade have allowed engineers to better analyze cases of hypersonic flight. The Space Shuttle Orbiter has increased over

30,000 pounds in weight since its initial design in 1974, resulting in limitations on its operational capability. One of these limitations is the allowable forward center of gravity location resulting from lateral-directional and longitudinal controllability constraints. One method to relax this limitation is to employ the use of a canard. A canard can produce the additional nose-up pitching moment to relax the center of gravity constraint as well as alleviate the need for large, lift-destroying elevon deflections required to maintain the high angles of attack required for effective hypersonic flight. A configuration is developed using known Orbiter aerodynamic data and a canard computational grid is generated. The Orbiter-canard configuration is analyzed at a Mach number of 5.8 and angle of attack of 50 degrees using flowfields generated by the OVERFLOW three-dimensional computer code. Comparison is made with a baseline solution and results are presented. GRA

N93-17809# National Aerospace Lab., Amsterdam (Netherlands). Fluid Dynamics Div.
APPLICATION OF AN EULER-EQUATION METHOD TO A SHARP-EDGED DELTA WING CONFIGURATION WITH VORTEX FLOW
H. W. M. HOEIJMAKERS and J. I. VANDENBERG 13 Aug. 1991 18 p Presented at AIAA 9th Applied Aerodynamics Conference, Baltimore, MD, 23-25 Sep. 1991 Previously announced in IAA as A91-53801 Sponsored by Netherlands Agency for Aerospace Programs
(NLR-TP-91; ETN-93-92007) Avail: CASI HC A03/MF A01

The flow about a wing-body-sting configuration with a 65-deg sharp-edged cropped delta wing and an under-wing body is simulated by solving the Euler requations. Results are presented for the configuration at a Mach number of 0.825 and at incidences ranging from 10- to 20-deg. For this transonic free stream Mach number a strong leading edge vortex as well as shocks develop in the flow field above the wing. For the wing-body-sting configuration the numerical solution is investigated and computational results are compared with experimental data. The investigation includes the analysis of the complex flow pattern in the near wake. The influence of the under wing body on the flow field about the wing is assessed by comparing the solution for the complete configuration with the solution obtained for the wing alone on a grid similar to that for the wing-body-sting configuration. ESA

N93-17819# Naval Postgraduate School, Monterey, CA.
A COMPUTATIONAL AND EXPERIMENTAL INVESTIGATION OF THE PROPULSIVE AND LIFTING CHARACTERISTICS OF OSCILLATING AIRFOILS AND AIRFOIL COMBINATIONS IN INCOMPRESSIBLE FLOW M.S. Thesis
KERRY S. NEACE Sep. 1992 123 p
(AD-A258019) Avail: CASI HC A06/MF A02

Computational and experimental methods have been used to systematically study one and two airfoils undergoing unsteady motion. First, a single airfoil analysis was done with the modified computer code, U2DIIF. Thrust, efficiency, and phase relationships were computed and compared to existing theoretical results. Furthermore, to help understand the dynamic stall process, relationships were developed between steady and quasi-steady pressure distributions for an airfoil undergoing a ramp motion. Next, an unsteady analysis for two airfoils was done with the modified computer code, USPOTF2. Again, thrust and efficiencies for interfering, harmonically oscillating airfoils were computed and compared to existing theoretical results. Furthermore, an analysis was completed on the effects of a harmonically oscillating airfoil on the pressure gradient of a stationary airfoil. Finally, flow visualization experiments were conducted using a low speed smoke tunnel at the Naval Postgraduate School (NPS). This experiment demonstrated the effects of a thrust producing, oscillating airfoil on the formation of the wake vortices. Furthermore, a flow visualization experiment was conducted in the NPS low speed wind tunnel, which demonstrated the beneficial influence of a secondary airfoil oscillating in the vicinity of a stationary airfoil at high angle-of-attack. GRA

N93-17855*# Purdue Univ., West Lafayette, IN. School of Aeronautics and Astronautics.
HOT FILM WALL SHEAR INSTRUMENTATION FOR COMPRESSIBLE BOUNDARY LAYER TRANSITION RESEARCH Final Report, 1 Jan. 1991 - 1 Nov, 1992
STEVEN P. SCHNEIDER 1992 214 p
(Contract NAG1-1201)
(NASA-CR-191360; NAS 1.26:191360) Avail: CASI HC A10/MF A03

Experimental and analytical studies of hot film wall shear instrumentation were performed. A new hot film anemometer was developed and tested. The anemometer performance was not quite as good as that of commercial anemometers, but the cost was much less and testing flexibility was improved. The main focus of the project was a parametric study of the effect of sensor size and substrate material on the performance of hot film surface sensors. Both electronic and shock-induced flow experiments were performed to determine the sensitivity and frequency response of the sensors. The results are presented in Michael Moen's M.S. thesis, which is appended. A condensed form of the results was also submitted for publication. Author

N93-17880# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
AERODYNAMIC DESIGN AND ANALYSIS OF FANS USING 3D COMPUTATIONAL CODES [CONCEPTION ET ANALYSE AERODYNAMIQUE DE SOUFFLANTES A L'AIDE DE CODES DE CALCUL 3D]
GEORGE KARADIMAS 1991 16 p In FRENCH Presented at 10th Congres Francais de Mecanique, Paris, France, 2-6 Sep. 1991
(DS-2140; ETN-93-93380) Avail: CASI HC A03/MF A01

The evolution of the design and analysis of high bypass ratio engine fans from an experimental basis to the use of digital simulation techniques is outlined. The choice of geometrical and aerodynamic parameters is considered together with the methodology for the design of the profiles and blades. Through achieved results, it is possible to directly correlate progress in computational fluid dynamics to fan performance improvements. The integrity of the fan is assumed by a mechanical analysis which interacts with the aerodynamics. Advantages of applying an aeromechanical approach to problems before carrying out the project are shown. The problems addressed include the following: the resistance of blades to ingestion of foreign bodies; and the prevention of supersonic flutter. It is concluded that digital techniques are beneficial and research should be continued along these lines. Three dimensional (3D) viscous flow and unsteady flow codes are already under development. ESA

N93-17884*# Sverdrup Technology, Inc., Brook Park, OH.
A NUMERICAL STUDY OF MIXING IN SUPERSONIC COMBUSTORS WITH HYPERMIXING INJECTORS Final Report
J. LEE Dec. 1992 22 p Sponsored by NASA. Lewis Research Center Original contains color illustrations
(Contract RTOP 505-62-40)
(NASA-CR-191027; E-7504; NAS 1.26:191027; AIAA PAPER 93-0215) Avail: CASI HC A03/MF A01; 4 functional color pages

A numerical study was conducted to evaluate the performance of wall mounted fuel-injectors designed for potential Supersonic Combustion Ramjet (SCRAM-jet) engine applications. The focus of this investigation was to numerically simulate existing combustor designs for the purpose of validating the numerical technique and the physical models developed. Three different injector designs of varying complexity were studied to fully understand the computational implications involved in accurate predictions. A dual transverse injection system and two streamwise injector designs were studied. The streamwise injectors were designed with swept ramps to enhance fuel-air mixing and combustion characteristics at supersonic speeds without the large flow blockage and drag contribution of the transverse injection system. For this study, the Mass-Averaged Navier-Stokes equations and the chemical species continuity equations were solved. The computations were performed using a finite-volume implicit numerical technique and

multiple block structured grid system. The interfaces of the multiple block structured grid systems were numerically resolved using the flux-conservative technique. Detailed comparisons between the computations and existing experimental data are presented. These comparisons show that numerical predictions are in agreement with the experimental data. These comparisons also show that a *number of turbulence model improvements are needed for accurate* combustor flowfield predictions. Author

N93-17929# National Aerospace Lab., Amsterdam (Netherlands). Aerodynamics Div.
BEYOND THE FREQUENCY LIMITS OF TIME-LINEARIZED METHODS
M. H. L. HOUNJET and B. J. G. EUSSEN 13 Jun. 1991 17 p
Presented at International Forum on Aeroelasticity and Structural Dynamics, Aachen, Germany, 1991
(NLR-TP-91216-U; ETN-93-93322) Avail: CASI HC A03/MF A01

Time linearized aerodynamic methods which usually operate in the frequency domain are known to suffer from frequency limitations especially in the transonic speed regime. Aerodynamic loads up to high frequencies are shown to be accurately obtained by applying methods which are based on exponentially diverging motions. A polynomial fit is made through the corresponding aerodynamic loads after which the fit is supposed to be valid also for general types of motion (analytical continuation). The convergence of iterative solvers in the aerodynamic methods is much improved, and a more than 50 percent reduction of computational cost may be achieved. It is further shown how existing time linearized methods which operate in the frequency domain can be modified to operate for diverging motions. Results of unsteady loads applications in two dimensional and three dimensional (3D) subsonic, transonic, and supersonic flow are shown. Results of an application to a 3D standard aeroelastic configuration in subsonic, transonic, and supersonic flow are presented. A description of the method of data fitting which was used in the examples is also given. ESA

N93-17934*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AN EXPERIMENTAL STUDY OF A TURBULENT BOUNDARY LAYER IN THE TRAILING EDGE REGION OF A CIRCULATION-CONTROL AIRFOIL Progress Report, 1 Sep. 1991 - 30 Sep. 1992
K. HEINEMANN and JEFF BROWN 8 Oct. 1992 7 p
(Contract NCC2-545)
(NASA-CR-191262; NAS 1.26:191262) Avail: CASI HC A02/MF A01

This report discusses progress made on NASA Cooperative Agreement NCC2-545, 'An Experimental Study of a Turbulent Boundary Layer in the Trailing-Edge Region of a Circulation-Control Airfoil' during the period 9/1/91 through 9/30/92. The study features 2-component laser Doppler velocimeter (LDV) measurements in the trailing edge and wake regions of a generic 2-dimensional circulation-control model. The final experimental phase of the study will be carried out in the Ames High Reynolds Number Channel 2 (HRC2) transonic blow-down-facility. During the 13-month period covered by this report, work continued on the development of the near-wall laser Doppler velocimeter (LDV) described in previous reports. Author

N93-17991# Defence Research Agency, Farnborough (England). Aerospace Div.
HEAT TRANSFER AND AERODYNAMICS OF A HIGH RIM SPEED TURBINE NOZZLE GUIDE VANE WITH PROFILED END WALLS
K. S. CHANA Jul. 1992 10 p
(AD-A258346; DRA-TM-AERO/PROP-8; DRIC-BR-312886) Avail: CASI HC A02/MF A01

It has been shown that the secondary flows present within turbine nozzle guide vanes have a marked effect on heat transfer. The horse-shoe and passage vortices, for example, have a major impact on platform and vane suction surface heat transfer. To investigate these effects further, heat transfer and aerodynamic measurements have been made on an annular transonic turbine nozzle guide vane ring, with three different platform geometries. The measurements were taken in the Isentropic Light Piston test facility at RAE Pyestock at representative values of engine Reynolds number, Mach number, and freestream gas-to-wall temperature ratio. This paper compares and discusses the *measured platform and vane suction surface* Nusselt and Mach number distributions for the three different endwall profiles. Comparisons with theoretical flow and heat transfer predictions are presented. GRA

N93-18086*# Eloret Corp., Sunnyvale, CA.
INCREASE OF STAGNATION PRESSURE AND ENTHALPY IN SHOCK TUNNELS
DAVID W. BOGDANOFF and JEAN-LUC CAMBIER *In its* Experimental Investigation of Nozzle/Plume Aerodynamics at Hypersonic Speeds 46 p 3 Dec. 1992
(Contract NCC2-487)
Avail: CASI HC A03/MF A02

High stagnation pressures and enthalpies are required for the testing of aerospace vehicles such as aerospace planes, aeroassist vehicles, and reentry vehicles. Among the most useful ground test facilities for performing such tests are shock tunnels. With a given driver gas condition, the enthalpy and pressure in the driven tube nozzle reservoir condition can be varied by changing the driven tube geometry and initial gas fill pressure. Reducing the driven tube diameter yields only very modest increases in reservoir pressure and enthalpy. Reducing the driven tube initial gas fill pressure can increase the reservoir enthalpy significantly, but at the cost of reduced reservoir pressure and useful test time. A new technique, the insertion of a converging section in the driven tube is found to produce substantial increases in both reservoir pressure and enthalpy. Using a one-dimensional inviscid full kinetics code, a number of different locations and shapes for the converging driven tube section were studied and the best cases found. For these best cases, for driven tube diameter reductions of factors of 2 and 3, the reservoir pressure can be increased by factors of 2.1 and 3.2, respectively and the enthalpy can be increased by factors of 1.5 and 2.1, respectively. Author

N93-18128# Cranfield Inst. of Tech., Bedford (England). College of Aeronautics.
THE AERODYNAMIC CHARACTERISTICS OF THE GOTTINGEN 797 AND WORTMANN FX63-137 AEROFOIL SECTIONS AT VERY LOW REYNOLDS NUMBERS M.S. Thesis
A. M. ROBINSON Sep. 1990 133 p
(ETN-93-92999) Avail: CASI HC A07/MF A02

Two aerofoil sections, the Gottingen 797 and the Wortmann FX63-137, were tested over the low Reynolds number range 151,000 to 285,000. Both clean and ribbed sections were tested with the aim of investigating the change in performance as a result of different spanwise rib spacing. Details of the wind tunnel and tests performed are given together with the results. The Wortmann demonstrated larger lift, and larger lift to drag ratios, than the Gottingen. Further, the Wortmann only required a two deg incidence decrease to close the hysteresis loop, whereas the Gottingen required at least five deg. Introducing ribs into the aerofoil design reduced the performance characteristics of both sections. The Gottingen exhibited the same lift loss for all three chord spacings, whereas the lift to drag ratio loss increased with wider rib spacings. The Wortmann experienced less of a lift reduction than the Gottingen, the loss being slightly greater for wider rib spacings. Similarly, the lift to drag ratio decreased proportionally to the rib spacing, but less than the Gottingen. Both aerofoils experienced severe hysteresis reduction. ESA

N93-18272# Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Aerospace and Ocean Engineering.
AN EXPERIMENTAL INVESTIGATION OF INTERACTING WING-TIP VORTEX PAIRS Technical Report, 1 Oct. 1990 - 30 Jun. 1992
J. S. ZSOLDOS and W. J. DEVENPORT 30 Jun. 1992 431 p

(Contract N00014-90-J-1909; N00014-91-J-1773)
(AD-A258471; VPI-AOE-191) Avail: CASI HC A19/MF A04

The interaction of trailing vortex pairs shed from the tips of two rectangular wings were studied through helium bubble flow visualizations and extensive hot wire velocity measurements made between 10 and 30 chordlengths downstream. The wings were placed tip to tip at equal and opposite angles of attack, generating pairs of co-rotating and counter rotating vortices. Meaningful hot wire measurements could be made because the vortices were found to be insensitive to probe interference and experienced very small wandering motions. The co-rotating pairs were observed to rotate around each other and merge. Upstream of the merging location, the vortices have approximately elliptical cores. These are surrounded by the two wing wakes which join together around the two cores. Flow in the vicinity of the cores appears fully developed. During the merging process, the cores rotate rapidly about each other, winding the wing wakes into a fine spiral structure. Merger roughly doubles the core size and appears to produce turbulence over a broad range of frequencies. The counter rotating pairs move sideways under their mutual induction and slightly apart; their flow structure changing little with downstream location. These cores remain fairly circular and do not become fully developed within 30 chordlengths of the measurements. GRA

N93-18275* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
REFLECTION TYPE SKIN FRICTION METER Patent
PROMODE R. BANDYOPADHYAY, inventor (to NASA) (AS&M, Inc., Hampton, VA.) and LEONARD M. WEINSTEIN, inventor (to NASA) 12 Jan. 1993 6 p Filed 8 Aug. 1991 Supersedes 92N-10008 (30 - 1, p 2)
(NASA-CASE-LAR-14520-1-SB; US-PATENT-5,178,004; US-PATENT-APPL-SN-742238; US-PATENT-CLASS-73-147; US-PATENT-CLASS-73-9; INT-PATENT-CLASS-G01M-9/00)
Avail: US Patent and Trademark Office

A housing block is provided having an upper surface conforming to the test surface of a model or aircraft. An oil film is supplied upstream of a transparent wedge window located in this upper surface by an oil pump system located external to the housing block. A light source located within the housing block supplies a light beam which passes through this transparent window and is reflected back through the transparent window by the upper surface of the oil film to a photo-sensitive position sensor located within the housing. This position sensor allows the slope history of the oil film caused by and aerodynamic flow to be determined. The skin friction is determined from this slope history. Internally located mirrors augment and sensitize the reflected beam as necessary before reaching the position sensor. In addition, a filter may be provided before this sensor to filter the beam.
Official Gazette of the U.S. Patent and Trademark Office

N93-18336# Naval Postgraduate School, Monterey, CA.
LIFT ENHANCEMENT USING A CLOSE-COUPLED OSCILLATING CANARD M.S. Thesis
DEAN C. SCHMIDT Sep. 1992 118 p
(AD-A257877) Avail: CASI HC A06/MF A02

A wind-tunnel study to investigate the effects of dynamic stall of a close-coupled canard on the canard/wing vortex interaction for increased lift enhancement was conducted. Two angles of attack of the model were studied: one at the first stall condition of the wing and one in the post-stall regime where a strong leading-edge vortex was formed. Baseline force and moment parameters were measured at mean canard deflections based on those determined to be optimum for the static case, as were mean values +/-3 degrees about the optimum. The amplitude of oscillation considered was +/-5 degrees about each mean; reduced frequencies tested were from 0.046 to 0.232. For most cases, lift was enhanced beyond the static-canard case at mean deflections equal to those at or greater than the static optimum value. The effective lift was decreased for mean deflections less than those previously determined to be optimum. Lift enhancements were generally 2 to 6 percent higher than the values determined with the static canard. The increased lift was generally independent of reduced frequency and peaked between k values of 0.1 to 0.2. GRA

N93-18378*# Eloret Corp., Sunnyvale, CA.
HYPERSONIC FLOWS AS RELATED TO THE NATIONAL AEROSPACE PLANE Semiannual Report, 1 Sep. 1991 - 31 May 1992
MARVIN KUSSOY, F. MENTER, and P. G. HUANG 30 Jul. 1992 6 p
(Contract NCC2-452)
(NASA-CR-191980; NAS 1.26:191980) Avail: CASI HC A02/MF A01

The study in the last 6 months has observed a clear evidence that the current two-equation models tend to under-predict flow separation and over-predict heat transfer rate near flow re-attachment regions. In hypersonic flow calculations, these model deficiencies appear to be even more pronounced. This is particularly true in the incapability of the model to predict the extent of the flow separation. Two major deficiencies of the current two-equation models in predicting complex hypersonic flows have been reported, i.e., under-prediction of flow separation and over-prediction of peak heat transfer rate. Two modifications to the k - epsilon model were reported and tested over a range of flows. Based on our limited study, the modified models have been found to give better agreements in both surface pressure and heat transfer predictions for several complex shock-wave boundary-layer interaction flows. However, in order to confirm our observation, more calculations will be performed in the future study covering a wider range of flows and conditions than reported here. Author

N93-18384*# Tennessee Univ. Space Inst., Tullahoma. Center for Space Transportation and Applied Research.
A WALL INTERFERENCE ASSESSMENT/CORRECTION SYSTEM Semiannual Report No. 3, Jul. - Dec. 1992
CHING F. LO, GLENN OVERBY, CATHY X. QIAN, W. L. SICKLES, and N. ULBRICH Dec. 1992 23 p
(Contract NAG2-733)
(NASA-CR-191889; NAS 1.26:191889) Avail: CASI HC A03/MF A01

A Wall Signature method originally developed by Hackett has been selected to be adapted for the Ames 12-ft Wind Tunnel WIAC system in the project. This method uses limited measurements of the static pressure at the wall, in conjunction with the solid wall boundary condition, to determine the strength and distribution of singularities representing the test article. The singularities are used in turn for estimating blockage wall interference. The lifting interference will be treated separately by representing in a horseshoe vortex system for the model's lifting effects. The development and implementation of a working prototype will be completed, delivered and documented with a software manual. The WIAC code will be validated by conducting numerically simulated experiments rather than actual wind tunnel experiments. The simulations will be used to generate both free-air and confined wind-tunnel flow fields for each of the test articles over a range of test configurations. Specifically, the pressure signature at the test section wall will be computed for the tunnel case to provide the simulated 'measured' data. These data will serve as the input for the WIAC method--Wall Signature method. The performance of the WIAC method then may be evaluated by comparing the corrected data with those of the free-air simulation. Author

N93-18585*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.
SIMULATION OF UNSTEADY ROTATIONAL FLOW OVER PROPFAN CONFIGURATION Final Report, Jun. 1986 - 30 Nov. 1990
RAKESH SRIVASTAVA and L. N. SANKAR 30 Nov. 1990 9 p
(Contract NAG3-730)
(NASA-CR-192234; NAS 1.26:192234) Avail: CASI HC A02/MF A01

During the past decade, aircraft engine manufacturers and

scientists at NASA have worked on extending the high propulsive efficiency of a classical propeller to higher cruise Mach numbers. The resulting configurations use highly swept twisted and very thin blades to delay the drag divergence Mach number. Unfortunately, these blades are also susceptible to aeroelastic instabilities. This was observed for some advanced propeller configurations in wind tunnel tests at NASA Lewis Research Center, where the blades fluttered at cruise speeds. To address this problem and to understand the flow phenomena and the solid fluid interaction involved, a research effort was initiated at Georgia Institute of Technology in 1986, under the support of the Structural Dynamics Branch of the NASA Lewis Research Center. The objectives of this study are: (1) the development of solution procedures and computer codes capable of predicting the aeroelastic characteristics of modern single and counter-rotation propellers; and (2) the use of these solution procedures to understand physical phenomena such as stall flutter, transonic flutter, and divergence. Author

N93-18602*# Iowa State Univ. of Science and Technology, Ames. Dept. of Aerospace Engineering and Engineering Mechanics.
ANALYTICAL SOLUTIONS TO CONSTRAINED HYPERSONIC FLIGHT TRAJECTORIES
PING LU 30 Nov. 1992 21 p Submitted for publication
(Contract NAG1-1255)
(NASA-CR-191987; NAS 1.26:191987) Avail: CASI HC A03/MF A01

The flight trajectory of aerospace vehicles subject to a class of path constraints is considered. The constrained dynamics is shown to be a natural two-time-scale system. Asymptotic analytical solutions are obtained. Problems of trajectory optimization and guidance can be dramatically simplified with these solutions. Applications in trajectory design for an aerospace plane strongly support the theoretical development. Author

N93-18617# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
PHOTOLUMINESCENT THERMOGRAPHY IN HYPERSONIC BLOWDOWN WIND TUNNEL: FEASIBILITY STUDY WITH PINPOINT MEASUREMENT Ph.D. Thesis - Caen Univ. [THERMOGRAPHIE PAR PHOTOLUMINESCENCE EN SOUFFLERIE HYPERSONIQUE A RAFALE: ETUDE DE FAISABILITE EN MESURE PONCTUELLE]
PIERRE BAUMANN 1992 202 p In FRENCH Original contains color illustrations
(ISSN 0078-3781)
(ONERA-NT-1992-8; ETN-93-93079) Avail: CASI HC A10/MF A03

A method of thermography which is based on the heat sensitivity of a photoluminescent compound applied to the model/object being studied is considered. When excited by ultraviolet light, the luminescent pigment emits visible radiation. Certain qualities of this radiation depend, among other factors, on the temperature of the luminescent coating. The uses of this method are investigated, and the possibility of applying it to thermal measurements in blowdown wind tunnels is addressed. The thermometric possibilities of the chosen configuration, phosphor, and method of luminescent analysis, were first evaluated outside the wind tunnel, and a few of the parameters likely to influence the measurement were determined. Preliminary blowdown wind tunnel tests gave a global indication of feasibility, even if the time response in heat fluxes depends greatly on the adequacy of the thermal properties of the coating and of the model material. Image acquisition and digital processing techniques will be applied at a later stage, to establish a complete thermal mapping. ESA

N93-18627# Max-Planck-Inst. fuer Stroemungsforschung, Goettingen (Germany).
NUMERICAL INVESTIGATION OF SWIRL-AIRFOIL INTERACTIONS IN TRANSONIC AREA Thesis [NUMERISCHE UNTERSUCHUNG VON WIRBEL-TRAGFLUEGEL-WECHSELWIRKUNGEN IM TRANSSONISCHEN GESCHWINDIGKEITSBEREICH]
KLAUS EHRENFRIED Oct. 1991 154 p In GERMAN
(ISSN 0436-1199)
(MPIS-8/1991; ETN-93-92730) Avail: CASI HC A08/MF A02

The two dimensional interaction between a vortex and an airfoil which characterizes the impulsive noise generated by helicopters is examined. The unsteady Euler equations were solved using a finite volume scheme on a triangulated instrument grid. The discretization was based on a conventional total variation diminishing method which was improved to reduce the numerical dissipation and to take into consideration the capture of shock waves. The vortex-airfoil interaction was investigated for various initial and boundary conditions. The numerical density distributions were compared with interferogram results from a wind tunnel experiment with a NACA profile. The computer distributions of vorticity and Mach number were analyzed. It is shown that the lift coefficient is not significantly modified by Mach number variations but the drag coefficient is strongly influenced by Mach number. ESA

N93-18648# Institut National de Recherche d'Informatique et d'Automatique, Le Chesnay (France). Programme 6: Calcul Scientifique, Modelisation et Logiciels Numeriques.
A BLOTTNER TYPE NUMERICAL MODEL FOR NONEQUILIBRIUM VISCOUS HYPERSONIC FLOWS IN UPWIND FINITE ELEMENTS [UN MODELE NUMERIQUE DE TYPE BLOTTNER POUR LES ECOULEMENTS HYPERSONIQUES VISQEUX HORS-EQUILIBRE EN ELEMENTS FINIS DECENTRES]
NATHALIE GLINKSY Jul. 1991 66 p In FRENCH Sponsored in part by Dassault Industries
(ISSN 0249-6399)
(INRIA-RR-1476; ETN-93-92651) Avail: CASI HC A04/MF A01

A method for solving the Navier-Stokes equations augmented with a nonequilibrium dissociation model for the numerical simulation of the hypersonic blunt body flow as it occurs in the nose region of a space vehicle during its atmospheric reentry is presented. In a pseudo-unsteady approach, a mixed spatial discretization is used: upwind finite volume for the convective terms and centered P1 finite elements for the diffusive terms, applicable to unstructured triangular meshes. The viscosity, conductivity, and diffusion terms are calculated by the Blottner model. The extension of the second order accuracy is constructed via the MUSCL technique. The introduction of the species equations is realized in an uncoupled approach using an equivalent lambda. The production rate terms are treated implicitly. Several methods to calculate the convective terms are compared. Numerical solutions of flows around blunt bodies and a double ellipse modeling of the European space shuttle Hermes are presented. ESA

N93-18652# Institut National de Recherche d'Informatique et d'Automatique, Le Chesnay (France). Programme 6: Calcul Scientifique, Modelisation et Logiciels Numeriques.
INFLUENCE OF THE PHYSICAL MODELLING OF VISCOUS TERMS ON HYPERSONIC FLOW COMPUTATIONS [INFLUENCE DE LA MODELISATION PHYSIQUE DES TERMES VISQUEUX SUR LE CALCUL D'ECOULEMENTS HYPERSONIQUES]
MARIA VITTORIA SALVETTI and MASSIMO PASSALACQUA (Rome Univ., Italy) Sep. 1991 55 p In FRENCH
(ISSN 0249-6399)
(INRIA-RR-1493; ETN-93-92658) Avail: CASI HC A04/MF A01

Some aspects of the influence of the physical modeling of transport terms on nonequilibrium viscous flow computations are analyzed. In particular, the implementation of four different viscous models for the numerical solution of external hypersonic flows are addressed. The general flow equations for a gaseous mixture in

chemical nonequilibrium and the employed chemical model are presented. The problem of modeling the transport terms from the kinetic theory of gases is detailed. Specifically, the Yos model, on which the transport coefficient calculation is based in the assumption of a binary mixture, is presented. With the numerical applications in mind, the description of four models of varying complexity is given. The discretization scheme applied to the numerical simulation of two dimensional external hypersonic flows is presented. The results obtained with the four models, for the blunt body and the double ellipse geometries in flow conditions similar to the conditions encountered by a space shuttle during the atmospheric reentry, are discussed. ESA

N93-18701# Office National d'Etudes et de Recherches Aerospatiales, Paris (France).
ELECTRON BEAM PROBING OF BLOW-DOWN HYPERSONIC FLOWS Ph.D. Thesis - Paris-Sud Univ. [SONDAGE PAR FAISCEAU D'ELECTRONS DES ECOULEMENTS HYPERSONIQUES EN RAFALES BREVES]
AJMAL KHAN MOHAMED 1992 251 p In FRENCH Original contains color illustrations
(ISSN 0078-3781)
(ONERA-NT-1992-7; ETN-93-93078) Avail: CASI HC A12/MF A03; 10 functional color pages

The feasibility of electron beam sounding of low density short lasting (approximately 20 ns) hypersonic flow is shown. Local and non intrusive measurements of density, vibrational and rotational temperatures and velocity in a low density flow of N2 or air are made with intensified optical multichannel analyzers. Detection of O2, N, O and NO were tried in the visible and near ultraviolet region; the NO molecule is found to be detectable through the NO(gamma) bands produced by the luminescent reaction with N2(A) metastables. Quantitative flow visualization using intensified charge coupled device cameras, in connection with a sweeping electron beam, seems to be possible to trace density contour maps of flow, insofar as the effects due to secondary excitations can be minimized. The use of a pulsed electron beam to tag a flow with plasma columns and spatial imaging of the movement of these luminous columns appears promising to measure the velocity and eventually to map the velocity field around a body set into the flow. ESA

N93-18771*# Institute for Computer Applications in Science and Engineering, Hampton, VA.
THE STABILITY OF A TRAILING-LINE VORTEX IN COMPRESSIBLE FLOW Final Report
JILLIAN A. K. STOTT (Manchester Univ., England) and PETER W. DUCK (Manchester Univ., England) Washington Dec. 1992 55 p Submitted for publication
(Contract NAS1-18605; NAS1-19480; RTOP 505-90-52-01)
(NASA-CR-189738; NAS 1.26:189738; ICASE-92-65) Avail: CASI HC A04/MF A01

We consider the inviscid stability of the Batchelor (1964) vortex in a compressible flow. The problem is tackled numerically and also asymptotically, in the limit of large (aximuthal and streamwise) wavenumbers, together with large Mach numbers. The nature of the solution passes through different regimes as the Mach number increases, relative to the wavenumbers. At very high wavenumbers and Mach numbers, the mode which is present in the incompressible case ceases to be unstable, while new 'center mode' forms, whose stability characteristics, are determined primarily by conditions close to the vortex axis. We find that generally the flow becomes less unstable as the Mach number increases, and that the regime of instability appears generally confined to disturbances in a direction counter to the direction of the rotation of the swirl of the vortex. Throughout the paper, comparison is made between our numerical results and results obtained from the various asymptotic theories. Author

N93-18781*# Eloret Corp., Sunnyvale, CA.
AN EXPERIMENTAL INVESTIGATION OF THE SEPARATING/REATTACHING FLOW OVER A BACKSTEP Progress Research Report, 1 Mar. 1992 - 31 Jan. 1993
SRBOLJUB JOVIC 31 Jan. 1993 21 p
(Contract NCC2-465)
(NASA-CR-192105; NAS 1.26:192105) Avail: CASI HC A03/MF A01

This progress report covers the grant period from March until the end of January 1993. Extensive data reduction and analysis of single and two-point measurements for a backward-facing experiment were performed. Pertinent results are presented in two conference papers which are appended to this report. The titles of the papers are as follows: (1) 'Two-point correlation measurements in a recovering turbulent boundary layer'; and (2) 'An experimental study on the recovery of a turbulent boundary layer downstream of the reattachment'. Author

N93-19003# Technische Univ., Delft (Netherlands).
PROPELLING FORCE AND RESISTANCE [STUWKRACHT EN WEERSTAND]
W. B. DEWOLF *In its* Professor Wittenberg: His Speciality and Versatility p 9-27 1991 In DUTCH
Copyright Avail: CASI HC A03/MF A01

Some of the problems of propulsion and aerodynamic drag of aircraft are treated. The distinction is made between forces due to external flow and to the action of the engine (called internal flow), as well as between gross and net propulsion force. The problem of engine-airframe integration is very important, especially in the context of turbofan engines. Some examples are given of wind tunnel research on aerodynamic interference between the propulsion installation and the rest of the aircraft. ESA

N93-19006# Technische Univ., Delft (Netherlands).
WHAT IS THE PROGRESS IN PROPULSION? [ZIT ER VAART IN VOORTSTUWING?]
P. A. O. G. KORTING *In its* Professor Wittenberg: His Speciality and Versatility p 59-80 1991 In DUTCH
Copyright Avail: CASI HC A03/MF A01

The activities of the TNO Prins Maurits Laboratory are outlined. These activities are mainly focused on propulsion systems for supersonic and hypersonic aircraft. The propulsion systems are based on rocket and ramjet techniques. There are civl and military research programs in the area of air breathing engines. The programs are for flight speeds from Mach 2 and higher. Pyrotechnical parts for the Vulcain engines of the European Ariane 5 launch vehicle were developed. Clean high energy and solid fuels are investigated. ESA

N93-19015*# High Technology Corp., Hampton, VA.
MODELING THE TRANSITION REGION
BART A. SINGER Washington Feb. 1993 91 p
(Contract NAS1-18240; RTOP 505-59-50-01)
(NASA-CR-4492; NAS 1.26:4492) Avail: CASI HC A05/MF A01

The current status of transition-region models is reviewed in this report. To understand modeling problems, various flow features that influence the transition process are discussed first. Then an overview of the different approaches to transition-region modeling is given. This is followed by a detailed discussion of turbulence models and the specific modifications that are needed to predict flows undergoing laminar-turbulent transition. Methods for determining the usefulness of the models are presented, and an outlook for the future of transition-region modeling is suggested. Author

N93-19053*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
UNDERWING COMPRESSION VORTEX ATTENUATION DEVICE Patent Application
JAMES C. PATTERSON, inventor (to NASA) 22 May 1992 7 p
(NASA-CASE-LAR-14744-1; NAS 1.71:LAR-14744-1; US-PATENT-APPL-SN-886998) Avail: CASI HC A02/MF A01

A vortex attenuation device is presented which dissipates a lift-induced vortex generated by a lifting aircraft wing. The device consists of a positive pressure gradient producing means in the form of a compression panel attached to the lower surface of the wing and facing perpendicular to the airflow across the wing. The

panel is located between the midpoint of the local wing cord and the trailing edge in the chord-wise direction and at a point which is approximately 55 percent of the wing span as measured from the fuselage center line in the spanwise direction. When deployed in flight, this panel produces a positive pressure gradient aligned with the final roll-up of the total vortex system which interrupts the axial flow in the vortex core and causes the vortex to collapse. NASA

N93-19273# National Aerospace Lab., Tokyo (Japan).
PROCEEDINGS OF THE NINTH NAL SYMPOSIUM ON AIRCRAFT COMPUTATIONAL AERODYNAMICS [DAI KAI KOUKUUKI KEISAN KUUKI RIKIGAKU SHINPOJUUMU RONBUNSHUU]
Dec. 1991 334 p In ENGLISH and JAPANESE Symposium held in Tokyo, Japan, 12-14 Jun. 1991
(ISSN 0289-260X)
(NAL-SP-16; JTN-92-80390) Avail: CASI HC A15/MF A03

The following topics were discussed: research activities on uses of computational grid method for flow simulations, numerical simulations of transitional flows, flows around airfoils and flying bodies, and flows inside pipes and air intake, hardware and operating system required for numerical wind tunnel, and applications of computational fluid dynamics in aircraft development. Author (NASDA)

N93-19274# Tokyo Univ. (Japan). Inst. of Industrial Science.
LES TURBULENCE MODELING USING DNS DATA BASE [DNS DETA BESU WO MOCHIITA LES RANRYUU MODERINGU]
KIYOSHI HORIUTI *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 1-8 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

The Smagorinsky model has been commonly used in Large Eddy Simulation (LES) of turbulent flow. Although LES computations or a variety of flows using this model have yielded acceptable results, it was necessary to incorporate several modifications into the model: (1) the model constant was optimized in different flows; and (2) the damping function was used to account for near wall effects. These modifications were generally ad hoc. Besides, a poor correlation of Reynolds stress model value with the Direct Numerical Simulation (DNS) exact value was reported. The resented paper's major objective is to address these issues and propose a new model which mitigates previous model's drawbacks by determining the proper energy scale in the subgrid scale eddy viscosity coefficient correlating with the channel flow DNS data. Author (NASDA)

N93-19275# Fujitsu Ltd., Tokyo (Japan).
A SIMPLE GRID GENERATION TECHNIQUE FOR HYPERSONIC FLOW AROUND COMPLEX CONFIGURATION [FUKUZATSU KEIJOU BUTTAI MAWARI NO CHOUONSOKURYUU NO TAME NO KANTANNA KOUSHI KEISEIHOU NI TSUITE]
YOKO TAKAKURA and SATORU OGAWA (National Aerospace Lab., Tokyo, Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 9-14 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

A simple grid generation technique which makes the grid fit a complex inner surface boundary with concavity and convexity orthogonally and also fit an outer surface boundary, is proposed here to simulate hypersonic flows around complex configuration. This technique is constituted algebraically by improving the hyperbolic grid generation method and considering the geometry. It is shown that two grids around hypersonic vehicles, a NASA shuttle and a NASDA shuttle H-2 Orbiting PlanE (HOPE), are successfully generated by using this technique. Author (NASDA)

N93-19276# Mitsubishi Heavy Industries Ltd., Tokyo (Japan).
COMPUTATION OF INTERNAL FLOWS USING UNSTRUCTURED TRIANGULAR MESHES [HIKOUZOU SANKAKUKEI KOUSHI NI YORU NAIBU NAGARE NO KEISAN]
HIDEO FUKUDA and KAZUOMI YAMAMOTO (National Aerospace Lab., Tokyo, Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 15-19 Dec. 1991 In JAPANESE
Avail: CASI HC A01/MF A03

Numerical methods using unstructured meshes, which are represented by the finite element method, caused a numerical instability in the computation of high Mach number flows with discontinuities (e.g., shock waves and contact discontinuities). In recent years, several researchers have developed solution algorithms using the unstructured meshes for high Mach number flows by introducing the upwind techniques which are well developed for the finite difference method. They have proposed the several methods to specify the distribution of variables in control volumes to construct higher order upwind schemes. However, the methods seem not to be well established especially for the 'cell centered' approach. In this paper, a procedure to construct higher order upwind schemes is examined, and the Van Leer's flux limiter is applied to the method. Computational results are presented to show the applicability of the method to high Mach number flows with shock waves. Author (NASDA)

N93-19277# National Aerospace Lab., Tokyo (Japan). Computational Sciences Div.
NUMERICAL COMPUTATIONS USING MULTI-DOMAIN TECHNIQUE [FUKUGOU KOUSHI NI YORU SUUCHI KEISAN]
SATORU OGAWA, YASUHIRO WADA, TOMIKO ISHIGURO, and YOKO TAKAKURA (Fujitsu Ltd., Tokyo, Japan) *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 21-26 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

The multidomain technique is used to solve the whole flow fields around the combined configuration of space vehicles. Several computational grids are overlapped with each other in the computational domain, and the solutions are combined by the interpolation scheme at the boundary of each grid. The Total Variation Diminishing (TVD) scheme of finite volume and post processing type is used to solve the Navier-Stokes equations for hypersonic flow. The numerical computations are performed for two problems, i.e., NASA space shuttle external tank rocket booster and NASDA HOPE (H-2 Orbiting Plane)/H-2 rocket/rocket boosters, and it is shown the results of numerical simulation using the present methods are reasonable. Author (NASDA)

N93-19278# Nissan Motor Co. Ltd., Tokyo (Japan).
NUMERICAL SIMULATIONS OF HYPERSONIC RAREFIED TRANSITION REGIME FLOWS: DSMC METHOD AND NAVIER-STOKES COMPUTATION [SENI RYOUIKI NAGARE NO SHIMYURESHON: DSMC HOU TO NABIA SUTOKUSU SUUCHI KAIHOU]
TORU SHIMADA, YASUHIRO WADA (National Aerospace Lab., Tokyo, Japan), and KATSUHISA KOURA (National Aerospace Lab., Tokyo, Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 27-32 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

Numerical solutions of the Direct Simulation Monte Carlo (DSMC) method and the Navier-Stokes equation with a no-slip or a slip wall boundary condition are obtained for hypersonic rarefied monatomic gas flows in the transition regime ($kn = 0.1$ to 0.001) around a finite length parallel flat plate and a circular cylinder. A comparison among these numerical solutions indicates that the DSMC method is well applied to a fully continuum flow regime and the Navier-Stokes equation is applicable to the transition flow regime by the use of the slip wall boundary condition. Author (NASDA)

N93-19279# National Aerospace Lab., Tokyo (Japan).
MONTE CARLO SIMULATION OF NORMAL SHOCK WAVE. PART 1: LENNARD-JONES POTENTIAL [SHOUGEKIHA NO MONTE KARURO SHIMYURESHON. 1: RENADO-JONZU POTENSHARU]
HIROAKI MATSUMOTO and KATSUHISA KOURA *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 33-35 Dec. 1991 In JAPANESE
Avail: CASI HC A01/MF A03

The Velocity Distribution Functions (VDF's) in an argon normal shock wave of upstream Mach number 7.8 and temperature 16 K are calculated using the null-collision direct simulation Monte Carlo method. The Lennard-Jones (LJ) potential is employed as a realistic intermolecular potential, where the deflection angle for molecular collisions is calculated by an accurate quadrature scheme. Some comparisons between the VDF's of the LJ potential, Maxwell molecule, and Maitland-Smith potential are made. Author (NASDA)

N93-19281# Nagoya Univ. (Japan). Dept. of Aeronautical Engineering.
ANALYSIS OF A 2-D AIRFOIL MOTION FLYING IN-PROXIMITY-TO A WAVY-WALL SURFACE: LIFTING-SURFACE-METHOD [HAJOU HEKIMEN JOU WO TOBU NIJIGENYOKU NO UNDOU KAISEKI: YOURYOKU MEN RIRON]
SHIGENORI ANDO, TETSU SAKAI, and KYOKO NITTA *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 41-49 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

An analysis of a two dimensional thin airfoil motion is presented, for cases when it flies over and in proximity to a wavy wall surface in an incompressible inviscid flow. Lifting surface technique is used. The results of computation agree satisfactorily with ones of another scheme, which is based on a finite difference method. Efficient integral domain on the wall surface is carefully settled. Some computations are included which suggest effect of many parameters on Wing In Ground effect vehicle (WIG) sea worthiness. Author (NASDA)

N93-19282# Nagoya Univ. (Japan). Dept. of Aeronautical Engineering.
ANALYSIS OF A 2-D AIRFOIL MOTION FLYING IN-PROXIMITY-TO A WAVY-WALL SURFACE: FINITE DIFFERENCE METHOD [HAJOU HEKIMEN JOU WO TOBU NIJIGENYOKU NO UNDOU KAISEKI: SABUNHOU]
KYOKO NITTA, SHIGENORI ANDO, and TETSU SAKAI *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 51-57 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

The lift on an airfoil flying over a wavy wall surface is calculated using a finite difference method, which was developed by J. Nakamichi to improve Low frequency TRANsonic flow solver for Two dimensional (LTRAN2) evolved by W. F. Ballhaus & P. M. Goorgian. In order to apply this LTRAN2 version to present problem, some manipulation on grid making system is needed. First, cases of a flat plate over a flat solid wall are calculated to check the coding prior to the cases of a moving wavy wall. Second, aerodynamic characteristics of a flat plate over a moving wavy wall are calculated, and third its motion is investigated. The calculated results are compared with those obtained by the lifting surface theory. The agreements are quite satisfactory. Author (NASDA)

N93-19283# Okayama Univ. of Science (Japan).
DEVELOPMENT OF A BOUNDARY ELEMENT METHOD PROGRAM FOR NUMERICAL ANALYSIS OF SUPERSONIC UNSTEADY FLOW [KYOUKAI YOUSOHOU NI YORU CHOUONSOKU HITEIJOURYUU NO SUUCHI KAISEKI PUROGURAMU KAIHATSU]
YUICHI MARUYAMA and TERUO SAWADA *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 59-63 Dec. 1991 In JAPANESE
Avail: CASI HC A01/MF A03

A boundary element method program for supersonic unsteady flow around arbitrary configurations has been developed. The fundamental formulation is based on Morino's method. Linear distribution of doublet is adopted to ensure the continuity of the strength on panel edges, while constant distribution is used for source. The numerical results are given for the cases of flows around oscillating cones. The real parts of the solutions are compared with the results of steady flow calculations and they are shown to be consistent with each other. Author (NASDA)

N93-19284# Kyushu Univ., Fukuoka (Japan). Dept. of Aeronautical Engineering.
NUMERICAL CALCULATIONS OF SEPARATING FLOWS AROUND OSCILLATING AIRFOIL [SHINDOU SURU YOKUKATA MAWARI NO HAKURIRYUU NO SUUCHI KEISAN]
SHIGERU ASO, ATSUHIRO SAKAMOTO (Nissan Motor Co. Ltd., Tokyo, Japan), and NORIYUKI KANEHIRA *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 65-70 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

Dynamic stall phenomena have been investigated numerically by solving incompressible Navier-Stokes equations by a third order upwind scheme in order to reveal the flow structure and mechanism of dynamic stall. At first, separated flows around a wing section at fixed attack angle are calculated and the results show excellent agreements with experiments which are conducted by the present authors. Separated flows around oscillating airfoil in pitch are calculated by using moving mesh system. The flow conditions are selected from experiments. The calculated separated region is small in pitching up process; and it becomes large in a pitching down process. Quite different characteristics of flow patterns between in a pitching up and pitching down processes are obtained. The hysteresis curves of C(sub L) and C(sub M) in dynamic stall are also simulated in the present calculations. Author (NASDA)

N93-19285# National Aerospace Lab., Tokyo (Japan).
NUMERICAL SIMULATION OF UNSTEADY LARGE SCALE SEPARATED FLOW AROUND OSCILLATING AIRFOIL [SHINDOUYOKU MAWARI NO HITEIJOU DAIKIBO HAKURIRYUU NO SUUCHI SHIMYURESHON]
KOJI ISOGAI *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 71-76 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

Numerical simulations of dynamic stall phenomenon of NACA0012 airfoil oscillating in pitch near static stalling angle are performed by using the compressible Navier-Stokes equations. In the present computations, a Total Variation Diminishing (TVD) scheme and an algebraic turbulence model are employed for the simulations of the unsteady separated flows at Reynolds number of 1.1 x 10(exp 5). The hysteresis loops of the unsteady pitching moment during dynamic stall are compared with the existing experimental data. The flow pattern and the unsteady pressure distributions during dynamic stall are also examined in detail. The qualitative features of the dynamic stall phenomenon, such as the behaviors of the total lift and pitching moment and the formation of the leading edge separation vortex are well reproduced by the present computations. Author (NASDA)

N93-19286# Science Univ. of Tokyo (Japan).
CALCULATIONS OF AERODYNAMIC FORCES ON A WING WITH THRUST USING BEM [KYOUKAI YOUSOHOU NI YORU SUIRYOKU TSUKI YOKU NO KUURIKI KEISAN]
MITSUNORI YANAGIZAWA *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 77-81 Dec. 1991 In JAPANESE
Avail: CASI HC A01/MF A03

A procedure for the numerical solution of steady flow past a wing with fans is described using a boundary element method in

potential flow. The effect of thrust is represented by doublet singularities. The method employs an aerodynamic panel code to simulate the flow of fan jet stream around an aircraft configuration. The configuration of a Vertical TakeOff and Landing (VTOL) transport in achieving a multijet lifting system is composed of lifting fans nested in the wing planform. The aerodynamic forces were calculated with the fundamental shape of 'fan in wing'. The result is that there are regions of negative lift behind the position of the lift fan on the wing. The general tendency of how they interact with the wing to produce the aerodynamic forces is understood. Author (NASDA)

N93-19292# National Aerospace Lab., Tokyo (Japan).
GENERATION OF LONGITUDINAL VORTICES IN SUPERSONIC FLOW [CHOUONSOKURYUU NI OKERU TATEUZU NO KEISEI]
TOSHIYUKI NOMURA, RYUJI ISHII (Kyoto Univ., Sakyoku, Japan), and MICHIO NISHIOKA (Osaka Prefectural Industrial Technology Research Inst., Enokojima, Japan) *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 123-128 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

A key technology for developing scramjet engine is to mix fuel hydrogen and oxygen in supersonic airstream rapidly and efficiently. So far, intensive basic researches have been made to establish the supersonic mixing technology. As a means of enhancing mixing by increasing the contact area of two different gas species, it is proposed in this paper to generate longitudinal vortices with spanwise periodic cut-outs at the trailing edge of the wedge shaped fuel injector. Furthermore, the wake of a flat plate with the same cut-outs is investigated to clarify the formation of the streamwise vortices. Three dimensional Euler equations are solved for the two cases with Chakravarthy and Osher typed Total Variation Diminishing (TVD) scheme. The computational results in the first case shows that longitudinal vortices are generated a little downstream of the trailing edge, shed into wake, and entrain nearby fluid. This is an evidence of rapid mixing. The second results show flow fields similar to the first, which proves that the generation of longitudinal vortices is mainly governed by the geometry of the cut-outs at the trailing edge. Author (NASDA)

N93-19294# Kawasaki Heavy Industries Ltd., Gifu (Japan). Technical Inst.
THE ROLE OF COMPUTATIONAL FLUID DYNAMICS IN AERONAUTICAL ENGINEERING. 9: ANALYSIS OF HYPERSONIC EQUILIBRIUM AIR FLOW [SEKKEI NI OKERU SUUCHI KEISAN NO KATSUYOU NI TSUITE. SONO: GOKU CHOUONSOKU HEIKOURYUU NO KAISEKI]
TAKUJI KISHIMOTO and AKIRA HANAMITSU (Kawasaki Heavy Industries Ltd., Kobe, Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 135-140 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

Numerical simulation of hypersonic flow around a two dimensional cylinder and a three dimensional complete reentry vehicle have been carried out by solving Euler and Navier-Stokes equations which incorporate the equation of state for an equilibrium air. The governing equations are solved by an implicit finite volume Total Variation Diminishing (TVD) upwind scheme using a two equation turbulence model for a viscous flow. Curve fits for the thermodynamic and transport properties of an equilibrium air adopted in order to estimate real gas effects. Convective fluxes are calculated by the Roe's approximate Riemann solver generalized for an equilibrium air. The results of hypersonic flow analysis using this code suggest that the real gas effects, such as chemical reaction, are not negligible to predict the hypersonic flow characteristics accurately. Author (NASDA)

N93-19295# National Aerospace Lab., Tokyo (Japan).
COMPUTATION OF RE-ENTRY FLOWS WITH TWO-TEMPERATURE MODEL [2 ONDO MODERU WO MOCHIITA SAITOTSUNYUU BUTTAI MAWARI NO SUUCHI SHIMYURESHON]
YASUHIRO WADA *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 141-147 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

Calculations are made for the shock tube flows around a circular cylinder and wedges in order to clarify the effects of the modelings which are included in the two temperature model: preferential dissociation and diffusive vibrational relaxation. A vibrational relaxation model, which is valid at high temperature and doesn't have the information immediately behind the shock wave, is suggested. In addition, thermal nonequilibrium effects are investigated by flow simulations around an Orbital Reentry EXperimental (OREX) vehicle. Author (NASDA)

N93-19296# National Aerospace Lab., Tokyo (Japan). Aerodynamics Div.
NUMERICAL CALCULATION OF HYPERSONIC NON-EQUILIBRIUM FLOW AROUND OREX [OREX MAWARI NO GOKU CHOUONSOKU KAGAKU HANNOU HIHEIKOURYUU NO KEISAN]
YUKIMITSU YAMAMOTO *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 149-152 Dec. 1991 In JAPANESE
Avail: CASI HC A01/MF A03

Chemically, nonequilibrium Navier-Stokes (N-S) code, using the finite rate 7 species chemical reactions, is developed and applied for the analysis of Orbital Reentry EXperiment (OREX) vehicle. Three dimensional forebody flow fields, where the shock stand off distance is severely shortened by the high temperature real gas effects, are evaluated. In addition, near wake flows are investigated in detail by using the zonal grids approach. Author (NASDA)

N93-19297# National Aerospace Lab., Tokyo (Japan). Aerodynamics Div.
NUMERICAL SIMULATION OF HYPERSONIC FLOW AROUND H-2 ORBITING PLANE (HOPE), PART 3 [HOPE MAWARI NO GOKU CHOUONSOKU SUUCHI SHIMYURESHON, 3]
YUKIMITSU YAMAMOTO *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 153-157 Dec. 1991 In JAPANESE
Avail: CASI HC A01/MF A03

Three dimensional upwind flux split Navier-Stokes (N-S) code is applied to the hypersonic flow around H-2 Orbiting PlanE (HOPE) 01 models. Numerical results were compared with experimental data of Numerical Wind Tunnel (NWT) and Calspan's shock tunnel. In order to study the aerodynamic environments of high Mach number area of HOPE flight trajectory, Mach number and real gas effects are analyzed by using the chemical nonequilibrium N-S code. Author (NASDA)

N93-19298# National Aerospace Lab., Tokyo (Japan).
THE 3D NAVIER-STOKES CALCULATION OF FLOW ABOUT SCRAMJET INLET WITH STRUT [SUKURAMUJETTO ENJIN NO NAGARE NO SANJIGEN NABIA SUTOKUSU KAISEKI: SUTORATTO TSUKI KUUKI TORIIREGUCHI]
TOMIKO ISHIGURO, KAZUYO SUEMATU, YASUHIRO WADA, and SATORU OGAWA *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 159-164 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

A numerical procedure to analyze a flow field through or around a Langley-typed scramjet engine inlet with a strut and an I-shaped thick cowl is proposed. To treat boundary conditions (wall, symmetry etc.) accurately, all boundaries are mapped onto faces of five rectangular parallelepipeds. The governing equations are the three dimensional full Navier-Stokes equations. The Total Variation Diminishing (TVD) scheme is applied for spatial discretizations and the Implicit Approximate Factorization (IAF) method, for time integration. To show capability of the numerical procedure, numerical simulations of flow have been carried out under Mach number 4 of free stream about four inlet models, whose struts differ in lengths but have the same contraction ratios. The result

has made no great difference from each other in inlet performance such as mass capture ratio and total pressure recovery ratio.
Author (NASDA)

N93-19299# Ishikawajima-Harima Heavy Industries Co. Ltd., Tokyo (Japan).

NUMERICAL SIMULATION OF FLOW FOR A SCRAMJET NOZZLE [SUKURAMUJETTO NOZURU RYUU NO SUUCHI SHIMYURESHON]

TARO TSUYUKI, YASUSHI HOSAKA (Tokyo Noko Univ., Japan), and FUMIO HIGASHINO (Tokyo Noko Univ., Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 165-172 Dec. 1991 In JAPANESE

Avail: CASI HC A02/MF A03

The objective of this paper is to compute the expansion of a supersonic flow through an internal and external nozzle and its interaction with the supersonic flow of free stream air. Furthermore, to calculate thrust and lift for a scramjet nozzle is attempted. The governing equations are the Navier-Stokes equations for two dimensional flows. The finite difference scheme employs an implicit upwind scheme. A turbulent model is adapted to the Baldwin-Lomax model. The diffusion, reaction and radiation of gas is neglected. Calculations are performed for the cases that have Mach number, temperature and pressure range at the combustor exit of 3,200 K and 1 to 2 atmospheres, respectively. The values on the outside of the afterbody and cowl are 3,500 K and 0.1 to 1 atmospheres respectively. The effects on the flow field, thrust and lift due to change of pressure, velocity and nozzle shape are studied. The results of the numerical calculations give different flow fields for underexpansion or overexpansion at the cowl exit. Consequently, the patterns of an asymmetric nozzle flow were found to be fixed by the degree of expansion at the cowl exit and no perfect correct expansion were found to have existed in these flows. Furthermore, the internal flow of the nozzle in case of the overexpansion was found to be largely influenced by the flow of free stream air.
Author (NASDA)

N93-19301# Nagoya Univ. (Japan). Dept. of Aeronautical Engineering.

TRANSONIC FLOW CALCULATION AROUND NACA-0012 [NACA-0012 YLKU MAWARI NO SENONSOKURYUU NO KEISAN]

ANDI EKA SAKYA, YOSHIAKI NAKAMURA, and MICHIRU YASUHARA *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 177-184 Dec. 1991

Avail: CASI HC A02/MF A03

Two turbulence models have been used to simulate a typical flow around NACA0012 at zero angle of attack. Those turbulence models are the Cebeci-Smith Model (CSM) and the Baldwin-Lomax Model (BLM). Analysis of these models in terms of turbulent boundary layer has also been carried out in which the differences in the predicted turbulent characteristics are made clear. The computed result is compared with the experimental data obtained from the transonic tunnel at Nagoya University. Author (NASDA)

N93-19308# Tohoku Univ., Sendai (Japan). Dept. of Aeronautics and Space Engineering.

NUMERICAL SIMULATIONS OF SUPERSONIC FLOW BY A FOURTH-ORDER COMPACT MUSCL TVD SCHEME [FOSU ODA KONPAKUTO MUSCL TVD SUKIMU NI YORU CHOUDNSOKU NAGARE NO SUUCHI SHIMYURESHON]

SATORU YAMAMOTO and HISAAKI DAIGUJI *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 221-226 Dec. 1991 In JAPANESE

Avail: CASI HC A02/MF A03

A fourth order compact Monotonic Upstream Centered Schemes for Conservation Laws (MUSCL) Total Variation Diminishing (TVD) scheme is proposed for simulating supersonic inviscid and viscous flows. The fundamental form of the present scheme is based on the second (third) - order accurate MUSCL finite difference scheme. One of the distinctive points by using this scheme is to be able to capture weak discontinuities such as slip lines or contact surfaces as well as shocks more accurately than the existing TVD scheme. The algorithm is much simpler than the Essentially Non-Oscillatory (ENO) scheme. Therefore, they can be easily applied to any ordinary numerical solvers based on the second (third) - order MUSCL scheme. In order to verify the reliability of the present scheme, unsteady inviscid and viscous supersonic flows are computed. The results show that the slip line as well as oblique shocks can be captured completely. Author (NASDA)

N93-19309# National Aerospace Lab., Kakuda (Japan). Research Center.

ANALYTICAL AND NUMERICAL STUDY ON STEADY MACH REFLECTION [MAHHA HANSHA KEIJOU KETTEI INSHI NI TSUITE]

TAKESHI KARITA, KATSUHIRO ITOH, and KOUICHIRO TANI *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 227-232 Dec. 1991 In JAPANESE

Avail: CASI HC A02/MF A03

It is not guaranteed for most of shock capturing schemes to obtain a physically relevant solution for complicated multi dimensional flow with shock wave reflection and crossing, such as steady Mach reflection. Ability of most of shock capturing schemes to simulate the steady Mach reflection has not been studied well because of the lack of solution for the steady Mach reflection in the large sense, i.e., not the solution for the vicinity of triple point, but for the whole Mach reflection flow region. In this paper, the analytical solution in the large sense is presented, and is used to study the ability of shock capturing scheme of the steady Mach reflection. Two inviscid flow simulations were made with the Harten-Yee type Total Variation Diminishing (TVD) scheme. The slip line configurations and the flows behind Mach stem by the scheme fairly agreed with the analytical ones, but the detailed flow structure, particularly around the triple point, did not agree well with the analytical solution. Author (NASDA)

N93-19310# Ishikawajima-Harima Heavy Industries Co. Ltd., Tokyo (Japan).

NUMERICAL SIMULATION OF THE FLOW THROUGH NON-UNIFORM AIRFOIL CASCADE [TAYOKUSO YOKURETSU MAWARI NO NAGARE NO SUUCHI SHIMYURESHON]

TAKASHI HOKARI, SHIGERU SAITO, ATSUSHIGE TANAKA, HISAO TAKEUCHI, KOJI MATSUNAGA, KAZUO KIKUCHI (National Aerospace Lab., Tokyo, Japan), and ATSUHIRO TAMURA (National Aerospace Lab., Tokyo, Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 233-237 Dec. 1991 In JAPANESE

Avail: CASI HC A01/MF A03

Numerical simulation for the cascade of aeroengine is usually done about circumferential same airfoils and is one pitch calculation. But in the real engine there are little changed airfoil or structures between cascade. So, one pitch calculation code was extended to multiple pitch and it was named as an analysis of nonuniform airfoil cascade. In this paper this code to bypass duct of a commercial jet engine was used and good agreement between analysis and experiment was obtained.
Author (NASDA)

N93-19311# Tokyo Univ. (Japan). Dept. of Aeronautics.

NUMERICAL STUDY ON TRANSVERSE HYDROGEN INJECTION INTO A SUPERSONIC FLOWFIELD [CHOUONSOKURYUU CHUU HENO SUISO NO SUICHOKU FUKIDA SHI NI KANSURU KENKYUU]

KAZUHIKO YOKOTA and SHOJIRO KAJI *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 239-244 Dec. 1991 In JAPANESE

Avail: CASI HC A02/MF A03

A supersonic flow field with transverse sonic injection of hydrogen is calculated by using the two dimensional Reynolds time averaged full Navier-Stokes equations and q-omega turbulence model developed by Coakley. A Yee's type second order explicit symmetric Total Variation Diminishing (TVD) scheme is applied

for spatial discretizations of convective terms of the equations. Wall pressure distribution of numerical results is compared with experimental data, and it is shown that the turbulence model is useful. In addition, the interactions between hydrogen injection and incident shock or expansion wave are simulated by the same procedure. The numerical results show that hydrogen distribution in the flow field becomes smaller by shock wave and larger by expansion wave slightly. When total temperature rises after an incident shock wave, which means a modeling of chemical reaction in flow, an interaction flow field with injection changes drastically. This suggests the importance of the similar study in chemically reacting flow. Author (NASDA)

N93-19312# Mitsubishi Electric Corp., Kamakura (Japan).
AERODYNAMIC HEATING ANALYSIS FOR AXISYMMETRIC BODIES IN SUPERSONIC FLOW [CHOUONSOKU HISHOUTAI TOUBU KEIJOU MAWARI NO KUURIKI KANETSU KAISEKI]
MASAYUKI KATAYAMA, RYUJIRO KUROSAKI, YOSHIKO NAKAMURA, SHIGERU ASO (Kyushu Univ., Fukuoka, Japan), and KAZUHIRO KUMASAKA (Mitsubishi Space Software Corp., Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 245-249 Dec. 1991 In JAPANESE
Avail: CASI HC A01/MF A03

Aerodynamic heating analyses have been performed for axisymmetric bodies in the supersonic flow. Both experiments using a shock tunnel and the computations corresponding to the experiments are conducted. Heat flux to the bodies such as a hemisphere cylinder and an ogive cylinder are measured. Flow conditions are: (1) Mach number M(sub infinity) = 4.25; (2) Reynolds numbers Re(sub infinity) = 2 to 3 x 10(exp 5), based on body radius; (3) stagnation temperatures T(sub 0) = 500 to 600 K; and (4) angle of attack *alpha* = 0 deg. Results of the experiments and the computations are summarized as follows. Heat flux to the hemisphere surface has the maximum value at the stagnation point and decreases smoothly downstream. Also the heat flux to the ogive surface is quite large in the vicinity of the tip and decreases gradually downstream in the case of fully laminar or fully turbulent flow. In the case of the flow including the transition, increase of heat flux caused by the transition of the boundary layer is observed. Lower and Upper - Alternating Direction Implicit (LU-ADI) difference scheme for compressible Navier-Stokes code has been used for the computations corresponding to the experiments. Computational results show good correlation to the experimental data obtained by the shock tunnel. Author (NASDA)

N93-19313# Kawasaki Heavy Industries Ltd., Gifu (Japan). Technical Inst.
THREE DIMENSIONAL CALCULATION OF FLOW INSIDE SUPERSONIC INLET [CHOUONSOKU KUUKI TORIIREGUCHI NAI NO NAGARE NI TSUITE]
AKIRA FUJIMOTO and KEISUKE SAWADA (Tohoku Univ., Sendai, Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 251-255 Dec. 1991 In JAPANESE
Avail: CASI HC A01/MF A03

A three dimensional Navier-Stokes calculation of flow inside a supersonic mixed compression inlet, designed for Mach 2.5, was carried out. A multiblock method was applied to the calculation grids. Complex configurations of bleed holes and throat slot were simulated in order to compare the solution with experimental data. As a result, detail information of the flow, which was usually difficult to obtain in an experiment, was obtained. On this inlet under the supersonic flow through conditions, the flow was found to be two dimensional in 0 percent of spanwise direction. In the vicinity of the sidewalls, however, three dimensional separation occurred along the cowl shock. The separation induced a vortex, and the vortex was stretched and swallowed into the throat slot. The ramp bleed ahead of the cowl shock impinge line was found to play an important role for avoiding the separation region to spread. A static wall pressure comparison between the results and the experimental data showed reasonable agreement.
Author (NASDA)

N93-19314# Nissan Motor Co. Ltd., Tokyo (Japan).
NUMERICAL SIMULATION OF FLOWS IN A SUPERSONIC AIR INTAKE [CHOUONSOKU EAINTEKU NI OKERU NAGARE NO SUUCHI KAISEKI]
NAOKI TAMURA, NOBUHIRO SEKINO, NAOHISA TUJIMURA, TORU SHIMADA, and KAZUYUKI HIRASAWA (Nissan Aerospace Engineering Co. Ltd., Tokyo, Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 257-262 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

Numerical solutions of Reynolds averaged Navier-Stokes equations are obtained for two dimensional flows inside a mixed compression supersonic air intake with its operation range from supercritical to subcritical. Computed wall pressure data are compared with wind tunnel data to show that their agreement is quite good except for the secondary postshock value, although the analytical value agrees quite well with the present computation. This discrepancy may be due to a three dimensional effect in the wind tunnel experiment. A comparison among numerical solutions for an inviscid flow obtained by the use of several types of numerical flux expressions indicates that solutions are strongly affected by the flux scheme and a possible reason for this can be attributed to the scheme's capability of resolving linear characteristic waves.
Author (NASDA)

N93-19315# Ishikawajima-Harima Heavy Industries Co. Ltd., Tokyo (Japan).
A NUMERICAL INVESTIGATION FOR SUPERSONIC INLET [CHOUONSOKU INTEKU NAI NAGARE NO SUUCHI SHIMYURESHON]
JUNJI SHIGEMATSU, KAZUO SHIRAISHI, ATSUSHIGE TANAKA, and KAZUOMI YAMAMOTO (National Aerospace Lab., Tokyo, Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 263-270 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

The flow field in high efficiency mixed compression inlet with throat cavity have been performed numerically by solving two dimensional compressible Navier-Stokes equations using Harten-Yee's Total Variation Diminishing (TVD) scheme. In the present study, the configuration of the experimental inlet is taken in computation as closely as possible. The flow field of the inlet including the throat cavity region is discretized and solved simultaneously with the external flow regions. The numerical results demonstrate the flow behaviors around the throat cavity for typical cases of the mass flow plug and wall bleed. Comparison with the experimental results for static pressure distributions and flow characteristics shows reasonable agreements and also detects the limitation of the two dimensional analysis. Author (NASDA)

N93-19316# Ishikawajima-Harima Heavy Industries Co. Ltd., Tokyo (Japan).
A NUMERICAL INVESTIGATION OF 3D TRANSVERSE INJECTION INTO THE SUPERSONIC FLOW BEHIND REARWARD FACING STEP [USHIRO MUKI SUTEPPU KOUHOU KARA NO CHOUONSOKU CHUU HENO SUICHOKU FUNSHA NO SUUCHI KAISEKI]
TOSHIRO FUJIMORI (Kyushu Univ., Fukuoka, Japan), YASUNORI ANDO (Kyushu Univ., Fukuoka, Japan), MASAFUMI KAWAI (Kyushu Univ., Fukuoka, Japan), YASUNORI OHMORI (Kyushu Univ., Fukuoka, Japan), and MASAHIRO FUKUDA (National Aerospace Lab., Tokyo, Japan) *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 271-276 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

Three dimensional Reynolds averaged full Navier-Stokes equation including chemical reactions solver is developed to predict flow fields in scramjet engine combustors. Using the above code, sonic gas transverse injections behind the rearward facing step into the M = 3.7 supersonic flow are investigated numerically.

The numerical results are compared with the result of the transverse injection on the flat plate. The comparison shows that mixing of injectant gas with main air flow is enhanced by the rearward facing step. Author (NASDA)

N93-19317# Mitsubishi Heavy Industries Ltd., Tokyo (Japan).
NUMERICAL CALCULATION OF FLOW FIELD IN SUPERSONIC COMBUSTION CHAMBER [CHOUONSOKU NENSHOUKI NAI NAGARE NO SUUCHI KAISEKI]
MAKOTO NISHIUCHI *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 277-282 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

There has been a renewed interest in hypersonic air breathing propulsion during the last decade. This interest is mainly associated with the study of hypersonic flight vehicles and space planes. A major focus of these studies is to develop new concept in propulsion technology. One of the propulsion concepts is based on supersonic combustion ramjet (Scramjet). However, because of the difficulties in experimentally simulating the actual flight environment, the details of the flow phenomena in the scramjet combustor, in particular the physics and fluid mechanism of the supersonic combustion process, are not well understood. Fortunately the recent progress of supercomputers and the advanced numerical algorithms have made it possible to analyze the combustor flow field with turbulence models and finite rate chemical reactions. In the present study, a numerical algorithm for supersonic flow with hydrogen and air combustion was developed, and two test cases were computed. These results are compared with existing available computational and experimental results. Author (NASDA)

N93-19318# Fuji Heavy Industries Ltd., Utsunomiya (Japan).
A NUMERICAL SIMULATIONS OF INNER FLOW OF SCRAMJET [SUKURAMUJETTO NAI RYUU NO SUUCHI SHIMYURESHON]
HIROSHI WAKAI *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 283-288 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

The flow fields over interior and exterior of simplified scramjet model are simulated numerically by two dimensional Navier-Stokes equations using an implicit finite difference scheme. For these simulations, the numerical scheme based on Chakravarthy Osher's Total Variation Diminishing (TVD) formulation is improved for multigrid application and Simple & Robust wall boundary conditions are applied. In this paper, the computed results are compared with two kinds of experiments, one is conducted by high speed wind tunnel and the other is conducted by hydraulic tank. Author (NASDA)

N93-19320# National Aerospace Lab., Tokyo (Japan).
WIND TUNNEL WALL INTERFERENCE CORRECTION AT SUBSONIC SPEEDS [AONSOKU NAGARE NI OKERU FUUDOUHEKI KANSHOU SHUUSEI]
HIDEO SAWADA *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 297-303 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

In the wall interference correction of the wind tunnel tests, the fundamental equation of the flow field must be linear everywhere inside the test section. However, the estimated wall interference corrections are often reasonable even in nonlinear cases. Some test results obtained at the NAL's two dimensional wind tunnel show the correction method is available even in the flow of Mach number 0.8. Available mathematical models for the ventilated wall characteristics are not accurate enough for the wall interference estimation. So, it is better to use the pressure distributions on the wind tunnel walls in place of the mathematical model to estimate the ventilated wall interference. This method is available in case of estimating the two dimensional wall interference. It is difficult to measure reliable pressure distributions over the four wall planes of the test section. So, the method has not been available in case of estimating the three dimensional wall interference. In principle, test sections with the adaptive walls will be solved the wall interference problem even in the transonic flow. More than 20 two dimensional test sections with the adaptive walls have been in use in the world. Author (NASDA)

N93-19321# National Aerospace Lab., Tokyo (Japan).
TWO PROBLEMS REDUCING THE DATA ACCURACY IN TRANSONIC WIND TUNNEL TESTING [FUUDOU SHIKEN NI OKERU 2, 3 NO MONDAI NI TSUITE: SENONSOKU DENO SHIKEN SEIDO WO SOGAI SURU YOUIN]
IWAO KAWAMOTO *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 305-311 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

Two problems concerning the data accuracy in transonic wind tunnel testing are described. One is the side wall boundary layer interference problem in the airfoil testing. In the transonic airfoil testing, it is believed that the side wall B.L. suction brings the improvement of the two-dimensionality of the airfoil surface flow. But it is not so simple. In NAL 2D high Reynolds number transonic wind tunnel, the measurements of side wall boundary layer thickness, Mach number distribution along center line and pressure distribution on NACA0012 airfoil were conducted with and without side wall boundary layer suction through a pair of rigimeshes. Following conclusions are derived in the present experimental studies. The B.L. suction system was not useful for the improvement of the airfoil surface flow, then theoretical side wall boundary layer correction such as Barnwell and Murthy methods should be employed to the data used solid side walls at the present time. Another problem presented here is transition Reynolds number of the experimental model. Using the AEDC standard cone, transition Reynolds number in several large transonic wind tunnels including NAL2m x 2mTWT are compared with flight data emphasizing the effects of back ground noise Cprms. Present comparative study shows that at low Mach number region Cprms does not promote the transition point forward and at high Mach number region the transition point is moved forward with large Cprms.
Author (NASDA)

N93-19323# Fuji Heavy Industries Ltd., Utsunomiya (Japan). Aircraft Factory.
WIND TUNNEL TESTS AND CFD IN FUJI HEAVY INDUSTRIES [FUJI JUUKOUGYOU NI OKERU FUUDOU SHIKEN TO CFD]
KOHEI TANAKA, HIDEHIRO HIROSE, and YASUHIRO KOSHIOKA *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 319-326 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

With the evolution of the Computational Fluid Dynamics (CFD) technology, the role of wind tunnel has come to be reevaluated. In this paper, the impact of CFD validation with wind tunnel is discussed, that is going to bring the needs for high accuracy of test data, and that will finally lead to more accurate new test technique, e.g., magnetic suspension, free from the mount interference or high Reynolds Number (RN) lowspeed wind tunnel, actually very useful for the low risk aircraft development. Also, wind tunnel facilities in Fuji Heavy Industries, Ltd. (FHI) Aerospace Division are introduced. With CFD technology and test technology, FHI has capability of wide range class airframe development; from lowspeed small target plane to space reentry vehicle.
Author (NASDA)

N93-19324# Kawasaki Heavy Industries Ltd., Gifu (Japan). Aircraft Research Lab.
WIND TUNNEL TEST AND CFD IN KAWASAKI HEAVY INDUSTRIES, GIFU [KAWASAKI JUUKOUGYOU GIFU NI OKERU FUUDOU SHIKEN TO CFD]
KENJI SAKAI *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 327-332 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

In Kawasaki Gifu, the wind tunnel tests and Computational

Fluid Dynamics (CFD) technologies have been mostly developed since the beginning of 1970. Three dimensional transonic wind tunnel test with 1 m x 1 m test section and three dimensional Navier-Stokes analysis are now available in the design work for many airplanes and aerospace vehicles. For example, some airplanes (STOL, T-4 etc.) and helicopters (BK117 etc.) were developed by using these useful technologies. This report presents the current status of these technologies in Kawasaki Gifu and the future roles respectively. Author (NASDA)

N93-19325# Mitsubishi Heavy Industries Ltd., Nagoya (Japan). Aerospace Systems.
WIND TUNNEL TESTING AND CFD SIMULATION IN MITSUBISHI HEAVY INDUSTRIES [MITSUBISHI JUUKOUGYOU NI OKERU FUUDOU SHIKEN TO CFD]
HIDEKI NOMOTO and JUNICHI MIYAKAWA *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 333-336 Dec. 1991 In JAPANESE
Avail: CASI HC A01/MF A03

Computational Fluid Dynamics (CFD) has established its unique position as a design tool in aerospace industries. As the CFD technology has evolved, the relationship with the conventional design tool of wind tunnel testing has also changed accordingly. This paper reviews the relationship of the two major technologies in Mitsubishi Nagoya. The typical CFD application are briefly introduced during the discussion. Author (NASDA)

N93-19340# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
EXPERIMENTAL INVESTIGATION OF THE AERODYNAMICS OF INDEPENDENTLY ROTATING CYLINDRICAL SHELLS M.S. Thesis
WALTER C. HOWERTON Dec. 1992 91 p
(AD-A258917; AFIT/GAE/ENY/92D-11) Avail: CASI HC A05/MF A01

The purpose of this thesis was to investigate experimentally the aerodynamic forces on two adjacent, independently rotating cylinders in a cross-flow. This investigation involved a force measurement setup which had the two cylinders mounted on a common support shaft, extending beyond the span of the wind tunnel test section, and supported by spoke rings with strain gages in the vertical and horizontal directions. This setup proved capable of measuring aerodynamic forces. The lift on the independently rotating cylinders was found to increase as one cylinder's angular speed increased while the other's remained constant, and decrease as the relative angular rate decreased. The drag coefficient was fairly constant over the range of velocity ratios tested, and minimal changes were noted with relative changes in angular speeds. Interactions between the two cylinders had the most effect on the lift and drag above 40 percent disparity in the angular rotation rates. The investigation also showed that for an offset angle of 30 deg on an approximately two-dimensional cylinder, the normal component of freestream velocity may be treated as the only significant contributor to the forces on the cylinder. GRA

N93-19364# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
APPLICATION OF THE PROGRAM PROFILE FOR THE DESIGN OF LOW-SPEED, LOW-OBSERVABLE CONFIGURATION AIRFOILS M.S. Thesis
GREGORY A. SHARP Dec. 1992 216 p
(AD-A258842; AFIT/ENY/GAE/92D-09) Avail: CASI HC A10/MF A03

The use of the program PROFILE for the design of low-speed, low-observable configuration airfoils was investigated. For our purposes, low-observable configuration is defined as being characterized by a small leading-edge radius of less than 1.18 percent chord and a thickness-to-chord ratio of 2.5 to 5.5 percent. A methodology was developed whereby the input parameters to prescribe the velocity distribution over the airfoil could be determined by a power law relationship. This relationship enables the designer to develop symmetric airfoils with the desired thickness-to-chord and leading-edge radius within the stated constraints. The resulting symmetric airfoils compared very well with NACA 4-digit airfoils of like thickness-to-chord ratio. The resulting airfoils have an increased stall angle compared to the NACA 4-digit airfoils. GRA

N93-19379*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ISSUES AND APPROACH TO DEVELOP VALIDATED ANALYSIS TOOLS FOR HYPERSONIC FLOWS: ONE PERSPECTIVE
GEORGE S. DEIWERT Oct. 1992 21 p
(Contract RTOP 506-40-41)
(NASA-TM-103937; A-92094; NAS 1.15:103937) Avail: CASI HC A03/MF A01

Critical issues concerning the modeling of low-density hypervelocity flows where thermochemical nonequilibrium effects are pronounced are discussed. Emphasis is on the development of validated analysis tools. A description of the activity in the Ames Research Center's Aerothermodynamics Branch is also given. Inherent in the process is a strong synergism between ground test and real-gas computational fluid dynamics (CFD). Approaches to develop and/or enhance phenomenological models and incorporate them into computational flow-field simulation codes are discussed. These models have been partially validated with experimental data for flows where the gas temperature is raised (compressive flows). Expanding flows, where temperatures drop, however, exhibit somewhat different behavior. Experimental data for these expanding flow conditions are sparse; reliance must be made on intuition and guidance from computational chemistry to model transport processes under these conditions. Ground-based experimental studies used to provide necessary data for model development and validation are described. Included are the performance characteristics of high-enthalpy flow facilities, such as shock tubes and ballistic ranges. Author

03

AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

A93-17798
PERFORMANCE DEGRADATION DUE TO HOAR FROST ON LIFTING SURFACES
R. J. KIND (Carleton Univ., Ottawa, Canada) and M. A. LAWRYSYN (Canadian Air Force, Canada) Canadian Aeronautics and Space Journal (ISSN 0008-2821) vol. 38, no. 2 June 1992 p. 62-70. Previously announced in STAR as N92-24866 Research supported by NSERC refs

This paper outlines an investigation into the effects of hoar frost roughness on the aerodynamic performance of airfoils and wings. The aerodynamic characteristics of actual, naturally grown, hoar frost were determined by testing several preserved samples in a wind tunnel. Boundary layer development over the samples was measured. Effective roughness height and spacing parameters were determined from the data. Computations were then carried out to assess the effects of frost on airfoil performance. These computations were done using a viscous/inviscid interaction approach. The computations indicate that frost in the leading edge region can have dramatic negative effects on airfoil and wing performance. Frost of only 0.4 nm height was predicted to cause take-off distance to increase by more than 80 percent when present in the leading edge region of a large transport aircraft's wing. On the other hand, frost beginning well downstream of the suction peak, for example at one-quarter chord, was predicted to have little effect. Author

A93-18345
AUTOMATION OF AIRCRAFT SERVICE TESTING TASKS USING THE AUTOMATIC CONTROL SYSTEM BEZOPASNOST'-3 [AVTOMATIZATSIIA ZADACH EKSPLUATATSIONNYKH ISPYTANII VS NA BAZE ASU 'BEZOPASNOST'-3']
K. P. DYNNIK *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 94-97. In Russian. refs
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The principal service testing tasks implemented in the automatic control system Bezopasnost'-3, designed for the computer-aided monitoring and evaluation of flight information, are reviewed. In particular, attention is given to the main data flows associated with service testing and means of data acquisition, storage, processing, analysis, and transfer. The testing tasks discussed relate to test documentation, general organization, flight testing, ground testing, and evaluation of test efficiency. V.L.

A93-18346
SEARCH STRATEGIES FOR A SEQUENCE OF BASELINE INDICES FOR BUILDING SECTIONS OF A FLIGHT-SAFETY AUTOMATIC CONTROL SYSTEM IN THE INTERACTIVE MODE [PUTI POISKA POSLEDOVATEL'NOSTI BAZOVYKH POKAZATELEI DLIA POSTROENIIA RAZDELOV ASU BEZOPASNOSTI POLETOV DIALOGOVYM METODOM]
R. I. VINOGRADOV and I. P. FADEEVA *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 99-104. In Russian. refs
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An approach is proposed whereby the Peterson safety principles and methods of mathematical logics are used to determine, in the dialog mode, a sequence of flight operation indices that would be optimal for a given flight unit. This sequence can then be used for building the database of the safety-oriented Bezopasnost'-3 automatic control system. V.L.

A93-18350
USING HELICOPTERS FOR TRANSPORTING LARGE AND HEAVY LOADS [ISPOL'ZOVANIE VERTOLETOV DLIA TRANSPORTIROVKI KRUPNOGABARITNYKH I TIAZHELOVESNYKH GRUZOV]
O. V. MUKVICH, V. Z. SHESTAKOV, R. V. SHCHAVINSKII, I. V. IUNGKIND, and V. Z. TSEITLIN *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 137-143. In Russian. refs
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An ecologically clean system for transporting oversize and heavy loads is proposed which uses the air cushion principle. The system represents a modular aerostatic air-cushion platform, each module consisting of a helium-filled inflated flexible toroidal balloon with internal partitions (for improved reliability). A special pneumatic lift with a platform is mounted inside the central shaft of the annular modules, providing a support for a helicopter or any other system capable of generating an air cushion; the load to be transported is fastened to a crossbeam attached to the modules at their perimeter. The system can be towed by different vehicles, such as a tractor, a tow boat, or a helicopter. Calculations for the powerplant of such a system are presented. V.L.

A93-18365
GRAPH-THEORY STUDIES OF THE POSSIBILITY OF OCCURRENCE OF FLIGHT ACCIDENTS AND INCIDENTS DURING THE TAKE-OFF UNDER SPECIAL OPERATING CONDITIONS [ISSLEDOVANIIA VOZMOZHNOSTI VOZNIKNOVENIIA AVIATSIONNYKH PROISSHESTVII I INTSIDENTOV NA ETAPE VZLETA VOZDUSHNOGO SUDNA V OSOBYKH SLUCHAIAKH EKSPLUATATSII METODOM TEORII GRAFOV]
IU. B. BUTROS *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 60-67. In Russian. refs
Copyright
The problem of predicting the probability of faults during the take-off and estimating the effect of faults on flight safety is examined. Factors determining the possibility of neutralizing the effect of faults are identified. The use of a graph-theory approach for calculating the probability of accident avoidance during the take-off is suggested. V.L.

A93-18542
CONCEPT OF CLOSED-CIRCUIT TV SYSTEM FOR TRANSPORT AIRCRAFT UNDER EXAMINATION
BERNIE FORWARD (Department of Transport, Air Accidents Investigation Branch, Farnborough, United Kingdom) ICAO Journal (ISSN 0018-8778) vol. 47, no. 10 Oct. 1992 p. 9-11.
Copyright
It is noted that the installation of closed-circuit television (CCTV) systems on public transport aircraft would improve flight safety and provide a very useful investigative tool. A review is presented of the development conducted on CCTV systems, where the cameras would be located, and some preliminary tests conducted during regular commercial flight operations. R.E.P.

A93-18712* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE ROLE OF SIMULATION IN DETERMINING SAFE AIRCRAFT LANDING SEPARATION CRITERIA
ROBERT A. STUEVER and ERIC C. STEWART (NASA, Langley Research Center, Hampton, VA) Oct. 1991 37 p. FAA, International Wake Vortex Symposium, Washington, Oct. 29-31, 1991, Preprint refs
The role of flight simulation in determining safe aircraft landing separation criteria is reviewed and discussed. A broad conclusion is made that previous vortex-encounter simulations were useful for predicting the general response of an aircraft in the presence of trailing vortices and the type of separation criteria to emphasize. These simulations, however, were generally limited in scope and validation. Broad requirements for an accepted simulation methodology are presented. Key technological issues are addressed, including the addition of high-fidelity vortex models and aircraft/vortex interaction effects in the simulation, and validation of simulations with experimental data. Finally, results from a preliminary one-degree-of-freedom simulation are shown. These indicate that reduced landing spacings may be feasible and that current aircraft categorizations should be reviewed. Author

A93-18780
ETOPS ACROSS THE ATLANTIC
P. D. HALL (Monarch Aircraft Engineering, Ltd., Luton, United Kingdom) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 2.1-2.14. refs
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The most important factor in the demonstrated success of extended range operations of twin-engined transport aircraft, 'ETOPS', is engine reliability. The in-flight shutdown (ISFD) rate is the common measure for evaluating engine acceptability for ETOPS. ISFD must be no higher than 0.05/1000 flying hours for 120-min operations, and 0.02/1000 for 180-min operations. An evaluation is made of current ETOPs operations in trans-Atlantic routes, for the case of such airliners as the B 757, using RB211 and PW2037 and PW2040 turbofans. O.C.

A93-20130#
INVESTIGATION OF LEADING EDGE ICE ACCRETION WITH CYCLICAL PNEUMATIC BOOT INFLATION
ROBERT C. GRIFFITHS (Texas A & M Univ., College Station) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0007) Copyright
The modelling of ice accretions on an airfoil undergoing cyclic pneumatic de-ice boot inflations was performed utilizing the numerical ice accretion prediction methodology, LEWICE. The

possibility of an ice bridge forming aft of the extent of the boot has been shown experimentally during flight tests with a twin engine, light utility aircraft. The appearance of this ice ridge suggests inadequate de-ice boot protection, resulting in severe aerodynamic lift and drag penalties. A theoretical simulation of these results utilizing LEWICE was accomplished, and wind tunnel tests were performed on the predicted ice shapes in the Texas A&M University Low Speed Wind Tunnel, utilizing a full scale model. Author

A93-20143#
MICRO-PHYSICAL MODELS FOR SIMULATING REALISTIC ICE ACCRETIONS
DAVID J. YURKANIN (U.S. Navy, Naval Air Warfare Center, Lakehurst, NJ) Jan. 1993 16 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0025)
The microphysical processes occurring on various scales during ice accretion are examined. The ice accretion phenomena and characteristics at each scale are described using consistent nomenclature and cataloging methods, and the highest scale is then described in full, using a detailed set of graphics to illustrate spacial and temporal phenomena. A summary is then presented of the required, enhanced, and novel models based on this scale study. I.S.

A93-20145#
PREDICTION OF THE ICE ACCRETION WITH VISCOUS EFFECTS ON AIRCRAFT WINGS
I. PARASCHIVOIU, P. TRAN, and M. T. BRAHIMI (Ecole Polytechnique, Montreal, Canada) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Bombardier/Canadair Group refs
(AIAA PAPER 93-0027) Copyright
A method using the Viscous-Inviscid Interaction technique has been developed for the calculation of ice accretion on three-dimensional wings of any cross section of planform geometry. This technique matches a panel method with a boundary layer correction to calculate the flow field. The resulting velocity field is subsequently used to compute water droplet trajectories and their impact points on the obstacle to obtain the quantity of ice accumulated on the wing. The method yields ice shapes that are in good agreement with numerical and experimental results in rime ice conditions. Author

A93-20147#
IMPACT ICE INTERFACE SHEAR STRESSES CAUSED BY BLADE BENDING AND TWISTING
R. J. SCAVUZZO, C. J. KELLACKEY, and M. L. CHU (Akron Univ., OH) Jan. 1993 6 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0030) Copyright
The objective of this paper is to present approximate formulas to estimate the interlaminar shear stresses in an ice layer adhered to an airfoil. Three separate loadings have been considered: stresses in impact ice on a rotating airfoil, interlaminar shear stresses caused by bending loads and interlaminar stresses caused by twisting. Following strength of materials methods, an approximate formula was developed to calculate interlaminar shear stresses at the interface between the impact ice and substrate. To evaluate the accuracy of this equation, stresses calculated from this formula are compared to finite element analyses. Both bending and torsional loadings are considered. In all cases, two layered composite elements were specified with an outer layer ice and an aluminum inner layer. Author

A93-20819
RECENT AIRCRAFT ACCIDENTS
NOBUO OCHI Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663) vol. 40, no. 467 1992 p. 627-639. In Japanese. refs
The trends of aircraft accidents are presented on the basis of world statistics from the International Civil Aviation Organization (ICAO). The main causes of aircraft accidents are analyzed, and the strength requirement for damage tolerant and multiple load path structures are illustrated. The fourth generation of aircraft, such as B767, B747-400, MD-11, and A320, are discussed with the emphasis on the flight management system, the flight control system, and crew resource management training. Y.P.Q.

A93-21627* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SENSING A CHANGE IN THE WIND
MICHAEL S. LEWIS (NASA, Langley Research Center, Hampton, VA) Aerospace America (ISSN 0740-722X) vol. 31, no. 1 Jan. 1993 p. 20-24, 30.
Copyright
A review is presented of new airborne sensors that enable better prediction of dangerous low-altitude windshear and microburst conditions. This research includes studies of the basic atmospheric physics and meteorology of microbursts that create windshear conditions; numerical simulation of windshear velocity, precipitation, and thermal fields; and simulation of the measurement performance of candidate sensor technologies. Based on this research, lidar, Doppler radar, and passive IR technologies all show promise for providing airborne forward-looking windshear detection. R.E.P.

A93-21718
THE USER FRIENDLY AIRLINER (THE 37TH ROY CHADWICK LECTURE)
A. C. D. CUMMING (British Airways, PLC, London, United Kingdom) Aeronautical Journal (ISSN 0001-9240) vol. 96, no. 959 Nov. 1992 p. 331-342.
Copyright
A development history and current status evaluation is presented for the extent to which commercial aircraft manufacturers have maximized the ease of operation and maintenance of their products. Operational 'user-friendliness' is furnished by advancements in autopilots, HUDs, microwave landing systems, ground-proximity and stall warnings, collision avoidance, and engine reliability monitoring. Maintenance and general safety improvements proceed from built-in test equipment, cabin fire-resistance enhancement, cabin water sprinklers, escape slides, and electronic entertainment equipment for passengers on long trips. O.C.

A93-22106
WEATHER-RELATED ACCIDENTS IN THE CANADIAN AVIATION INDUSTRY - AN ANALYSIS OF THE CHIEF CONTRIBUTORY FACTORS
TONY B. SHAW (Brock Univ., St. Catharines, Canada) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 19-22. refs
Copyright
The paper investigates environmental and meteorological factors in weather-related accidents in the Canadian aviation industry, namely all weather phenomena that an aircraft encounters during take-off, while enroute to its destination, and during landing. Emphasis is placed on those problems associated with aircraft damage and personal injury due to adverse weather conditions over Canadian territory. P.D.

A93-22109
NEW INITIATIVES FOR AVIATION METEOROLOGY TRAINING - 1989 THROUGH 1991
TIMOTHY H. MINER (AVMET Foundation, Denver, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 31-34. refs
Copyright
Efforts to substantially enhance pilot meteorology training since the third international aviation meteorology conference are described. It is recommended that there be follow-on training for the professional pilot in light of new technologies that exist in the

aviation weather system. The flight review process for all pilots should include an examination of the civilian pilot's level of weather knowledge. Accident statistics must be reviewed to validate the need to increase pilot meteorology training. P.D.

A93-22110
IMPROVING WEATHER QUESTIONS ON FEDERAL AVIATION ADMINISTRATION EXAMS
JACK WILLIAMS (USA Today, Arlington; Av-Ed Aviation Education Professionals, Falls Church, VA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 35-38. refs
Copyright
The current examinations of the Federal Aviation Administration are reviewed with an eye to singling out some of their deficiencies. Emphasis is placed on questions for private pilots. Changes that could be made with relative ease while retaining the current examination format are suggested. Suggestions for more wide-ranging improvements are presented as well. P.D.

A93-22112* National Aeronautics and Space Administration, Washington, DC.
HAZARD ASSESSMENT AND COCKPIT PRESENTATION ISSUES FOR MICROBURST ALERTING SYSTEMS
CRAIG WANKE and R. H. HANSMAN, JR. (MIT, Cambridge, MA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 45-50. Research supported by MIT and FAA refs
(Contract NGL-22-009-640)
Copyright
Issues pertaining to the development of an alerting system for microbursts in the terminal area are studied. A methodology for evaluating microburst hazard criteria is developed on the basis of batch aircraft flight simulations. A preliminary evaluation of a selected set of hazard criteria is performed. The results indicate that the total headwind change along the aircraft flight path ('total divergence') does not correlate well with the approach degradation caused by microbursts. A preliminary piloted simulator study on cockpit presentation of wind shear alerts in verbal, alphanumeric, and graphical formats is performed. Graphical alerts were found to produce better decision-making and lower crew workload, and to be greatly preferred by pilots. Alphanumeric alerts were not well liked and exhibited no advantages over standard verbal radio communications. P.D.

A93-22115
THE IMPORTANCE OF PROPER AVIATION WEATHER DISSEMINATION TO PILOTS - AN AIRLINE CAPTAIN'S PERSPECTIVE
ROBERT L. SUMWALT, III (Air Line Pilots Association, Washington) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 60-65.
Copyright
The importance of proper aviation weather dissemination to pilots is illustrated via several NTSB aircraft accident and incident reports. The disadvantages of the most commonly used method of relaying convective weather information to pilots (preflight and inflight), the 'connect the dots' game, are discussed. ATIS and weather information datalink are being developed so that pilots can receive this information on a cockpit CRT instead of having to leave the ATC frequency to obtain it on another frequency. P.D.

A93-22121
A COMPARISON OF SEVERAL AIRBORNE MEASURES OF TURBULENCE
MICHAEL R. POELLOT and CEDRIC A. GRAINGER (North Dakota Univ., Grand Forks) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 90-93. refs
(Contract DTFA01-87-C-00019)
Copyright
A number of objective measures of turbulence are compared and related to subjective observations for use in evaluating the turbulence algorithms. Derived turbulence parameters are listed. Graphs illustrate the frequency distribution of subjective turbulence intensities as a function of the maximum absolute value of G and as a function of epsilon exp 1/3 computed from true airspeed. P.D.

A93-22143
IMPACT OF WEATHER ON AVIATION - A GLOBAL VIEW
C. H. SPRINKLE and K. J. MACLEOD (World Meteorological Organization, Geneva, Switzerland) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 191-196. refs
Copyright
The historical involvement of meteorology, both national and international, with aviation is traced, and the present status and expected development trends are examined. The World Weather Watch and the World Area Forecast System are reviewed. The aeronautical meteorological information system comprises three distinct phases in providing aeronautical information to the aviation community, namely, the observing/detecting of information; information assimilation and forecast and warning message formulation; and dissemination. C.A.B.

A93-22144
IMPROVED EFFICIENCY OF AIR TRANSPORTATION THROUGH AVIATION WEATHER SYSTEM MODERNIZATION
CAROL W. BRANSCOME, EDWIN L. KEITZ, and AGAM N. SINHA (Mitre Corp., McLean, VA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 197-201. refs
Copyright
The potential impact of weather system modernization of the efficiency of the air transportation system is discussed. Improvements are to occur in data acquisition, communications, data processing and product separation, and dissemination of products and services. Automated surface observations will be available from more than 1500 locations to provide minute-by-minute observations in the local area in addition to conventional hourly and special observations for all users. Improvements in winds aloft observations will be provided by a network of wind profilers and the implementation of an automated aircraft reporting system. This system is to provide 80,000 to 100,000 aircraft reports per day over the conterminous U.S. when the system is fully utilized. New geostationary and polar orbiting satellites will provide improved visible and IR imagery. The installation of long-range Doppler weather radars will result in significant improvements in the detection, location, and characterization of en route convective activity and other types of hazardous weather. C.A.B.

A93-22153* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A SUMMARY OF INVESTIGATIONS OF SEVERE TURBULENCE INCIDENTS USING AIRLINE FLIGHT RECORDS
P. F. LESTER (San Jose State Univ., CA), R. C. WINGROVE, and R. E. BACH (NASA, Ames Research Center, Moffett Field, CA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 257-261. refs
(Contract NCC2-315)
Copyright
Work done on the NASA-Ames data base of digital flight records from airliners involved in severe turbulence incidences is summarized. The summary includes descriptions of the archived cases, data processing procedures, estimated errors, analysis

procedures, and significant results to date. Thirteen severe turbulence cases are listed. C.A.B.

A93-22156
THE AERONAUTICAL VOLCANIC ASH PROBLEM
JERALD DECKER and ESTHER L. MCKAY (NOAA, National Weather Service, Silver Spring, MD) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 270-273.
Copyright

The recommended practices on observations and reports of volcanic activity by meteorological stations are summarized. It is shown that the inclusion of ash clouds on significant weather forecast charts can only occur if the volcano erupts shortly before or during the preparation of a chart. The provision of long-term (up to 12 hr and beyond) volcanic ash information by outlining the ash cloud on significant weather charts is confusing when the area delineated is larger than it might be or if the chart is prepared for an eruption that only turns out to be mostly steam or does not exist. It is conlcuded that the best way to inform flight planners about volcanic ash is to include a statement such as 'see potential significant meteorological information for volcanic ash' near the volcano on all significant weather charts until the volcano becomes inactive again. C.A.B.

A93-22160
TURBULENCE AVOIDANCE
DANIEL T. STACK (Air Line Pilots Association, Herndon, VA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 283-286. Research supported by Northwest Airlines, Inc refs
Copyright

Statistics on clear air turbulence and recommendations for avoiding it are presented. When unforeseen turbulence is encountered, available inflect data should be preferred to preflight data in order to make the best choice for avoidance. In mountain wave conditions, the best choice is alternate routing. The next best option is to be 3000-4000 ft above the tropopause or 4000-5000 ft below it. P.D.

A93-22172
A QUANTITATIVE METHOD TO ESTIMATE THE MICROBURST WIND SHEAR HAZARD TO AIRCRAFT
GREGORY P. BYRD (New York State Univ., Brockport) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 335-340. refs
(Contract NSF ATM-89-14546)
Copyright

An aircraft wind shear performance index, the F-factor, is applied to the microburst problem in order to characterize the microburst wind shear threat to achieve a reliable assessment of aircraft performance hazards from forward-look sensors. This is accomplished on the basis of output from the Terminal Area Simulation System convective cloud model develped at Langley. The present method for estimating the F-factor agrees well with low-altitude F-factor estimates derived from TASS model simulations, Doppler radar analysis, and flight data recorders. It is a simple method that is formulated on basic physical principles, e.g., mass continuity. It can be easily integrated into forward-look on-board sensors to provide a reasonable estimate of the total F-factor, and represents a substantial improvement over hazard estimates derived solely from the quasi-horizontal air motions measured by the sensors. P.D.

A93-22181
VOLCANIC ASH AND AIRCRAFT OPERATIONS
EDWARD MILLER (Air Line Pilots Association, Marysville, PA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 378-383.
Copyright

A brief review of the damage sustained by aircraft due to volcanic ash over the past few decades is presented. The dust is abrasive and capable of causing serious damage to aircraft engines, control surfaces, windshields and windows, and landing lights. The dust can also clog the pitot static systems that help calculate airspeed and altitude, and it can damage sensors that deliver electronic data to technically automated systems used to fly modern aircraft. Recommendations for reducing the volcanic ash hazard to aviation are presented. They include the development of an aircraft-mounted passive IR system for discriminating and locating ash clouds, the development of a tunable lidar, and the development of a UV spectrometer to detect high concentrations of SO2. P.D.

A93-23069#
THE FAA AIRCRAFT ICING FORECASTING IMPROVEMENT PROGRAM - VALIDATION OF AIRCRAFT ICING FORECASTS IN THE DENVER AREA
M. K. POLITOVICH, R. M. RASMUSSEN, P. L. HAAGENSON, W. R. SAND (NCAR, Boulder, CO), J. A. MCGINLEY, E. R. WESTWATER, J. R. SMART, and S. C. ALBERS (NOAA, Boulder, CO) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract DTFA01-90-A-02005)
(AIAA PAPER 93-0393)

Progress toward improved in-flight aircraft icing forecasts is being made as part of the FAA Icing Forecasting Improvement Program. A data ingest and analysis scheme with 10-km horizontal resolution shows promise for diagnosing supercooled liquid water if accurate cloud locations and temperature soundings are available. Preliminary versions of automated forecasting schemes based on temperature and relative humidity output from operationally-available numerical models are being used and tested, and appear to provide useful guidance based. Detailed mesoscale models with explicit cloud liquid fields are being developed as our research in this area continues. Author

A93-23239# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CLOSE-UP ANALYSIS OF AIRCRAFT ICE ACCRETION
R. J. HANSMAN, JR., KENNETH S. BREUER, DIDIER HAZAN (MIT, Cambridge, MA), ANDREW REEHORST, and MARIO VARGAS (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15360 refs
(Contract NAG3-666; NGL-22-069-640; RTOP 505-68-10)
(AIAA PAPER 93-0029) Copyright

Various types of ice formation have been studied by analysis of high magnification video observations. All testing was conducted in the NASA Lewis Icing Research Tunnel (IRT). A faired 8.9 cm (3.5 in.) diameter metal-clad cylinder and a 5.1 (2 in.) aluminum cylinder were observed by close-up and overview video cameras for several wind tunnel conditions. These included close-up grazing angle, close-up side view, as well as overhead and side overview cameras. Still photographs were taken at the end of each spray along with tracings of the subsequent ice shape. While in earlier tests only the stagnation region was observed, the entire area from the stagnation line to the horn region of glaze ice shapes was observed in this test. The modes or horn formation have been identified within the range of conditions observed. In the horn region, Horn Type A ice is formed by 'dry' feather growth into the flow direction and Horn Type B is formed by a 'wet' growth normal to the surface. The feather growth occurs when the freezing fraction is near unity and roughness elements exists to provide an initial growth site. Author

A93-23243# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ADVANCEMENTS IN THE LEWICE ICE ACCRETION MODEL
WILLIAM B. WRIGHT (Sverdrup Technology, Inc., Brook Park,

OH) Jan. 1993 18 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15402 refs
(Contract NAS3-25266; RTOP 505-68-10)
(AIAA PAPER 93-0171)

Recent evidence has shown that the NASA/Lewis Ice Accretion Model, LEWICE, does not predict accurate ice shapes for certain glaze ice conditions. This paper will present the methodology used to make a first attempt at improving the ice accretion prediction in these regimes. Importance is given to the correlations for heat transfer coefficient and ice density, as well as runback flow, selection of the transition point, flow field resolution, and droplet trajectory models. Further improvements and refinement of these modules will be performed once tests in NASA's Icing Research Tunnel, scheduled for 1993, are completed. Author

A93-23244# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ICE ACCRETION AND PERFORMANCE DEGRADATION CALCULATIONS WITH LEWICE/NS
MARK G. POTAPCZUK (NASA, Lewis Research Center, Cleveland, OH), KAMEL M. AL-KHALIL (National Research Council, Washington), and MATTHEW T. VELAZQUEZ (MIT, Cambridge, MA) Jan. 1993 21 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15354 refs
(Contract RTOP 505-68-10)
(AIAA PAPER 93-0173) Copyright

The LEWICE ice accretion computer code has been extended to include the solution of the two-dimensional Navier-Stokes equations. The code is modular and contains separate stand-alone program elements that create a grid, calculate the flow field parameters, calculate the droplet trajectory paths, determine the amount of ice growth, calculate aeroperformance changes, and plot results. The new elements of the code are described. Calculated results are compared to experiment for several cases, including both ice shape and drag rise. Author

A93-23245# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ICE ACCRETION PREDICTION FOR A TYPICAL COMMERCIAL TRANSPORT AIRCRAFT
C. S. BIDWELL (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 22 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15522 refs
(Contract RTOP 505-68-10)
(AIAA PAPER 93-0174) Copyright

Ice accretion calculations were made for a modern commercial transport using the NASA Lewis LEWICE3D ice accretion code. The ice accretion calculations were made for the wing and horizonal tail using both isolated flow models and flow models incorporating the entire airplane. The isolated flow model calculations were made to assess the validity of using these simplified models in lieu of the entire model in the ice accretion analysis for full aircraft. Ice shapes typifying a rime and a mixed ice shape were generated for a 30 minute hold condition. In general, the calculated ice shapes looked reasonable and appeared representative of a rime and a mixed ice conditions. The isolated flow model simplification was good for the main wing except at the root where it overpredicted the amount of accreted ice relative to the full aircraft flow model. For the horizontal tail the size and amount of predicted ice compared well for the two flow models, but the position of the accretions were more towards the upper surface for the aircraft flow model relative to the isolated flow model. This was attributed to downwash from the main wing which resulted in a lower effective angle of attack for the aircraft tail. Author

N93-16455# Wichita State Univ., KS. National Inst. for Aviation Research.
AVIATION SAFETY RESEARCH AT THE NATIONAL INSTITUTE FOR AVIATION RESEARCH WICHITA STATE UNIVERSITY: A REPORT TO THE FAA TECHNICAL CENTER
WILLIAM H. WENTZ, JOHN J. HUTCHINSON, and DAVID R. ELLIS Feb. 1992 120 p
(NIAR-92-2) Avail: CASI HC A06/MF A02

Viewgraphs of a report presented to the FAA Technical Center on Aviation Safety Research is included. Topics covered include a review of 1990 contract tasks, report of 1989 contract, program plan for 1991 contract, follow-on items, and schedule for next program review. These projects covered topics such as scratch effects on fatigue of new alloys; survey of automated scanning and robotics system for aircraft inspection; crash analysis of aircraft seats; toward standardization of design procedures for rotor containment - turbine engine failure; and failure mechanisms in composite structures manufactured using contemporary techniques. L.R.R.

N93-16834# National Transportation Safety Board, Washington, DC.
SPECIAL INVESTIGATION REPORT: FLIGHT ATTENDANT TRAINING AND PERFORMANCE DURING EMERGENCY SITUATIONS
9 Jun. 1992 59 p
(PB92-917006; NTSB/SIR-92/02) Avail: CASI HC A04/MF A01

This report reviews recent aviation accidents and incidents, Federal Aviation Regulations related to flight attendant training, and flight attendant training programs from 12 air carriers. Evidence from recent accident and incident investigations revealed that some flight attendants did not perform emergency duties in accordance with their air carrier training programs. The Safety Board believes that the ability of flight attendants to perform their duties successfully during emergency situations is directly related to the quality of their emergency training. As a result of this special investigation, the Safety Board issued 13 recommendations to the FAA about flight attendant training. Author

N93-18031# Computer Resource Management, Inc., Herndon, VA.
NATIONAL AIRSPACE SYSTEM FLIGHT PLANNING OPERATIONAL CONCEPT NAS-SR-131
WILLIAM TRENT, THOMAS PICKERELL, and HAROLD NELSON, JR. Sep. 1992 55 p
(Contract DTFA01-91-Y-01004)
(DOT/FAA/SE-92/4) Avail: CASI HC A04/MF A01

This document is an operational concept of the flight planning processing system which will be in place upon implementation of the Federal Aviation Administration (FAA) National Airspace System (NAS) Plan. Flight planning encompasses all activities involved in the preparation of a flight, including the information retrieved by the pilot prior to the flight and used to make go/no go decisions; the information conveyed by the pilot to the NAS in the form of a flight plan; and all NAS-related services which support these activities. The objective of this document is to describe the relationship between subsystems, facilities, information, and operators/users involved in the flight planning process. In addition, the elements and operations of the NAS Plan are mapped into the flight planning requirements stated in the National Airspace System Requirement Specification (NASSRS, NASSR-1000). Several types of block diagrams are used to illustrate systems connectivity and operational flow. Scenarios are also derived to describe the flight planning process from a user's perspective. This concept along with seven other operational concepts will complete the description of the system requirements as described in the NASSRS. The eight operational concepts are: communications, navigation, monitoring, maintenance and support, system effectiveness, air defense, flight planning, and traffic control and airspace management. Author

N93-18036# Wichita State Univ., KS. National Inst. for Aviation Research.
THE AIRLINE QUALITY REPORT, 1992
BRENT D. BOWEN and DEAN E. HEADLEY Mar. 1992 34 p
(NIAR-92-11) Avail: CASI HC A03/MF A01

The Airline Quality Rating 1992 is a summary of month-by-month quality ratings for major domestic U.S. airlines

operating during 1991. Using the Airline Quality Rating (AQR) system and performance data for each airline for the calendar year of 1991, ratings and rankings are reported. The Airline Quality Rating was developed and announced in early 1991 as an objective method of comparing airline performance on multiple factors important to consumers. Compiled industry results that yield average rankings for all airlines are included in this Airline Quality Report 1992. The AQR rating system is detailed in NIAR Report 91-11, The Airline Quality Rating, issued in April, 1991, by the National Institute for Aviation Research at The Wichita State University. This current research monograph, NIAR Report 92-11 contains a brief summary of the AQR methodology, comments and strategic observations about the airline industry that grow from analysis of the ratings and from the authors perceptions regarding industry trends and events over the past years, and detailed data and charts that track comparative quality for major domestic airlines across the 12 month period. Author

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

A93-17751
EUROPEAN NAVIGATION INTO THE 21ST CENTURY; PROCEEDINGS OF THE CONFERENCE, LONDON, UNITED KINGDOM, FEB. 12, 1991
London Royal Aeronautical Society 1991 77 p.
(ISBN 0-903409-82-8) Copyright

The present conference on European navigation into the 21st century encompasses area navigation and future requirements for Western Europe, a military plan for European navigation in the next century, frequency considerations for navigation in the area, and reviews of civil satellite navigation systems. Also addressed are airborne trials of navigation technologies such as the Loran-C, the status and projected developments for the OMEGA/VLF system, the window of opportunity for European navigation, and a review of flight management systems. (For individual items see A93-17752 to A93-17757) C.C.S.

A93-17752
THE FUTURE OF AREA NAVIGATION IN WESTERN EUROPE
BERNARD PERRY (Civil Aviation Authority, National Air Traffic Services, London, United Kingdom) *In* European navigation into the 21st century; Proceedings of the Conference, London, United Kingdom, Feb. 12, 1991 London Royal Aeronautical Society 1991 p. 2.1-2.4.
Copyright

A critical review of existing point-source radio navigation aids in Western Europe is conducted, and area navigation (RNAV) is proposed as a means for future European coverage. A frame of reference is developed for the progressive implementation of RNAV with attention given to the need for cooperation between states. Also described are developments in guidance material, legislation, and technologies required for the full-scale implementation of RNAV in Western Europe. C.C.S.

A93-17754
EUROPEAN NAVIGATION INTO THE 21ST CENTURY - FREQUENCY CONSIDERATIONS
M. W. KENYON (Radiocommunications Agency, London, United Kingdom) *In* European navigation into the 21st century; Proceedings of the Conference, London, United Kingdom, Feb. 12, 1991 London Royal Aeronautical Society 1991 p. 4.1-4.6.
Copyright

Current European spectrum use is examined with predictions of near-term frequency-allocation changes for services in the spectrum ranging from 0 kHz to 275 GHz. The paper demonstrates that current radiodetermination allocations are adequate for future applications, and a meeting of the International Telecommunication Union is required to address further needs. C.C.S.

A93-17756
AIRBORNE TRIALS OF LORAN-C
I. D. BIRCH (Royal Aerospace Establishment, Farnborough, United Kingdom) *In* European navigation into the 21st century; Proceedings of the Conference, London, United Kingdom, Feb. 12, 1991 London Royal Aeronautical Society 1991 p. 6.1-6.13. refs
Copyright

Limited flight trials of the Loran-C in the Mediterranean and North Atlantic are described with attention given to European noise considerations and potential accuracy improvements. The Loran system is shown to provide the required accuracy for marine, airborne, and land-based navigation, although enhanced coverage is only feasible with an improved receiver for the noise environment in Europe. C.C.S.

A93-17757
FLIGHT MANAGEMENT SYSTEMS
E. D. BAILEY (Royal Aerospace Establishment, Bedford, United Kingdom) *In* European navigation into the 21st century; Proceedings of the Conference, London, United Kingdom, Feb. 12, 1991 London Royal Aeronautical Society 1991 p. 8.1-8.8.
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Flight management systems (FMSs) are described in terms of their performance in navigation and in terms of their impact on the development of air traffic management (ATM) systems. The aspects of FMSs reviewed include their use as a database for an aircraft's lateral flight path, and the FMS computer is discussed in terms of the radio navigation aids employed. C.C.S.

A93-17797
ANALYSIS OF LORAN-C PERFORMANCE IN THE PEMBERTON AREA, B.C
G. LACHAPELLE, B. TOWNSEND (Calgary Univ., Canada), and B. B. MEYERS (Transportation Development Centre, Montreal, Canada) Canadian Aeronautics and Space Journal (ISSN 0008-2821) vol. 38, no. 2 June 1992 p. 52-61. refs

The reliability, stability and availability of Loran-C signals for potential land and air navigation around Pemberton Airport, British Columbia, were investigated utilizing data gathered continuously over the period May 1989 to February 1990. An additional sequence of data recorded at the same site during May-June 1987 was made available to study the multiyear stability of the system. R.E.P.

A93-17835
ARINC 629 DATABUS; PROCEEDINGS OF THE CONFERENCE, LONDON, UNITED KINGDOM, SEPT. 24, 1991
London Royal Aeronautical Society 1991 83 p.
(ISBN 0-903409-95-X) Copyright

The present conference on the ARINC 629 databus encompasses the conversion of the DATAC system to the present ARINC technology, the status and terminal technology of the databus system, experience with the ARINC 629 on specific aircraft, and validation and testing procedures and results for the databus. Specific issues addressed include applications of the 629 databus to the Boeing 7J7 aircraft, the fiberoptic implementations used in the ARINC optical bus, and proposed applications of the ARINC 629 to civil aircraft avionics. Also addressed are the ARINC 629 databus technologies including the multichip modules, monitoring enhancements, the modular computer architecture, and assessment criteria for the system. (No individual items are abstracted in this volume) C.C.S.

A93-18543
EFFECTIVE 406-MHZ ELT DEMONSTRATES THE POTENTIAL TO SAVE MORE LIVES

CAY-R. BOQUIST (International Civil Aviation Organization, Air Navigation Bureau, Montreal, Canada) ICAO Journal (ISSN 0018-8778) vol. 47, no. 10 Oct. 1992 p. 12-14.
Copyright

New-generation emergency locator transmitters (ELT) to be carried by all aircraft will facilitate rapid location of distress sites anywhere in the world. A review of development work performed on ELTs and regulations proposed for their use are presented. R.E.P.

A93-18553
THE SSR MODE-S DATA-LINK [LES TRANSMISSIONS DE DONNEES DU SSR MODE S]
FRANCIS BRANGIER Navigation (Paris) (ISSN 0028-1530) vol. 40, no. 160 Oct. 1992 p. 464-472. In French. refs
Copyright

The secondary surveillance radar (SSR) mode-S is a new concept that allows full compatibility with current SSR. It also provides for air/ground data-link. The principal characteristics and performance of this system are presented along with some of the mode-S global implementation programs. R.E.P.

A93-18554
RECEIVER AUTONOMOUS INTEGRITY MONITORING (RAIM) AVAILABILITY FOR SUPPLEMENTAL GPS NAVIGATION
KAREN L. VAN DYKE (DOT, Cambridge, MA) Navigation (Paris) (ISSN 0028-1530) vol. 40, no. 160 Oct. 1992 p. 481-494. refs
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An examination of GPS RAIM availability for supplemental navigation based on the approximate radial-error protection (ARP) technique is presented. This technique applies ceiling levels for the ARP figure of merit to screen out bad detection geometries under worst case bias conditions. The ARP criterion for each phase of flight is based on the integrity specifications called for in the RTCA SC-159 supplemental MOPS for GPS. Employing the ARP criterion, detailed analysis was conducted to determine the availability of RAIM over the CONUS, Europe, North Atlantic, North Pacific, and Central East Pacific during en route, terminal, and nonprecision approach phases of flight. The results show that RAIM is not available 100 percent of the time, even with 24 operational satellites. This is because there are times when only four satellites are visible, preventing RAIM detection altogether, and other occasions when the geometry of the visible satellites has an ARP that exceeds the ARP ceiling value. R.E.P.

A93-18555
AIRBORNE MLS EQUIPMENT [L'EQUIPEMENT BORD MLS]
JOSEPH HETYEI (Aviation Civile, Service Equipements Embarques, France) Navigation (Paris) (ISSN 0028-1530) vol. 40, no. 160 Oct. 1992 p. 496-515. In French. refs
Copyright

The utilization of the current ILS and the future MLS are described. The onboard MLS equipment including angular and DME measures is presented. In-flight considerations concerning the transition from ILS to MLS are discussed. R.E.P.

A93-18932
DESIGN CONSIDERATIONS FOR AIR-TO-AIR LASER COMMUNICATIONS
W. L. CASEY, G. R. DOUGHTY, R. K. MARSTON, and J. MUHONEN (Rockwell International Corp., Richardson, TX) *In* Free-space laser communication technologies III; Proceedings of the Meeting, Los Angeles, CA, Jan. 21, 22, 1991 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 89-98. refs
Copyright

The requirements of lasercom systems to support strategic data exchange between airborne command post aircraft and intraformation data links among fighter aircraft or low-flying, close-formation aircraft are examined, and the systems link analysis necessary to select preferred approaches are presented. The state of key technologies such as lasers, detectors, filters, coding, acquisition, etc. form a basis for structure conceptual systems that meet mission requirements. There have been recent advances in these key technologies, which will significantly improve air-to-air lasercom system performance. The resultant systems are low-risk and could be developed in minimum time. The preferred systems are described, and conclusions and recommendations that could lead to the development of a prototype terminal for one of the above missions are presented. C.A.B.

A93-20007
APPLICATIONS OF SPACE TECHNIQUES TO CIVIL AVIATION OPERATIONS [LES APPLICATIONS DES TECHNIQUES SPATIALES AUX OPERATIONS AERIENNES CIVILES]
OLIVIER CAREL (Direction de la Navigation Aerienne, Paris, France) and BRIEUC SPINDLER L'Onde Electrique (ISSN 0030-2430) vol. 72, no. 6 Nov.-Dec. 1992 p. 50-54. In French. refs
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It is noted that civil aviation currently lacks reliable means of communication and navigation in many airspaces. It is suggested that space techniques can provide an efficient solution with complete global coverage. However, they necessitate the integration of communications with private telephone and the integration of navigation with military systems. These techniques alone cannot solve the problem of airspace congestion over the major industrial countries. It is concluded, however, that the integration of various techniques in a unique mobile telecommunications network and the institution of automatic periodic position reports will gradually improve the situation. L.M.

A93-20008
THE GPS SYSTEM - SATELLITE RADIO-NAVIGATION [LE SYSTEME 'GPS' - RADIONAVIGATION PAR SATELLITES]
JEAN-FRANCOIS JEHL (Sextant Avionique, Valence, France) L'Onde Electrique (ISSN 0030-2430) vol. 72, no. 6 Nov.-Dec. 1992 p. 55-59. In French.
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The signal characteristics, potential performance, and main limitations of the Global Positioning System (GPS) are first described. The principles for the measurement and calculation of PVT (position, velocity, time) positioning parameters are then given. The GPS receiver architecture details are presented, and the microelectronic technologies that are applied to modern receivers are discussed. Future GPS developments, including complementary satellite systems, are presented, and a prospective view of the uses foreseen for these new techniques is also given. L.M.

A93-21127
DESCRIPTION AND CAPABILITIES OF THE NAVCORE-V GPS RECEIVER ENGINE
STEWART P. TEASLEY, ROBERT M. CLARK, and STEVEN A. GRONEMEYER (Rockwell International Corp., Dallas, TX) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 59-67.

An overview is presented of the hardware design of NavCore V, the commercial GPS receiver engine which is designed to provide system integrators with the core GPS capability to support a variety of products. Emphasis is given to design aspects that support low-cost manufacturing required for a commercial receiver. Particularly valuable features of the design include: high performance five-channel capability, small size, low power consumption, robust RF front end, and ease of integration. Software is also discussed from the perspective of achieving maturity in a new commercial design. Recommendations are made for integrating the engine into a variety of applications. C.D.

A93-21128
DIGITAL HOPPING GPS/GLONASS RECEIVER
JAMES DANAHER and RONALD R. GERLACH (3S Navigation, Laguna Hills, CA) *In* ION GPS-91; Proceedings of the 4th

International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 69-76. refs

A highly integrated GPS/GLONASS (Global Orbiting Navigation Satellite System) receiver is described in which individual satellite tracking channels can be arbitrarily assigned to any GPS or GLONASS satellite. The receiver has a single analog radio frequency/intermediated frequency front end with a fixed frequency local oscillator (LO). Custom-developed digital application specific integrated circuits track the selected GPS and GLONASS satellites and provide correlation measurements of software processing. Frequency hopping between GPS and GLONASS is done entirely in the digital domain, eliminating the expensive frequency hopping LO seen in earlier designs. Implementing the receiver in VLSI with multiple channels on a single integrated circuit will lead to considerable size reductions and cost savings as commercial multiple-channel GPS/GLONASS receivers are introduced in the near future. C.D.

A93-21130
USCG HU-25A/GPS INTEGRATION
TSUNG-HSUN WU and ROBERT W. TAFEL (U.S. Navy, Naval Air Development Center, Warminster, PA) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 117-127. refs

GPS integration into the U.S. Coast Guard HU-25A medium range search (MRS) and rescue aircraft, including the antenna, is reviewed. Information on the original HU-25A avionics system is presented. The results of tests conducted during various phases of the integration, which demonstrated the advantages of integrating GPS into the MRS avionics system, are summarized. C.D.

A93-21141
THE EFFECTS OF IONOSPHERIC ERRORS ON SINGLE-FREQUENCY GPS USERS
RICHARD L. GREENSPAN, AVRAM K. TETWSKY, JAMES I. DONNA (Charles Stark Draper Lab., Inc., Cambridge, MA), and JOHN A. KLOBUCHAR (USAF, Phillips Lab., Hanscom AFB, MA) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 291-297. refs

Experimental data from different sources show that navigation errors by GPS users resulting from ionospheric delays are smaller than one might predict even if the ionospheric correction is not applied to time delay measurement. These results could be interpreted to suggest that there are some GPS single-frequency users whose navigation accuracy would not suffer if they omitted the ionospheric delay correction. It is argued here that this is not a proper conclusion except when GPS selective availability is turned on. A simple mathematical analysis shows how the excess propagation delay is weighted into the navigation solution. This result is interpreted to show that it is the variation of delays from one satellite to another that drives the navigation error. A new metric for obtaining the coefficients in the ionospheric model is suggested. C.D.

A93-21142
INTEGRATED USE OF GPS AND GLONASS IN CIVIL AVIATION NAVIGATION. II - EXPERIENCE WITH GLONASS
P. MISRA, E. BAYLISS, R. LAFREY, M. PRATT, and R. HOGABOOM (MIT, Lexington, MA) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 321-331. Research supported by FAA refs

GLONASS measurements taken over a six-month period have been analyzed for positioning accuracy and system upkeep. The results show that the positioning accuracy provided by GLONASS is comparable to that from GPS when the feature of Selective Availability (SA) in the latter is off. In the presence of degradation of the GPS signal via SA, the GLONASS position estimate would be clearly better. The navigation messages are analyzed in order to understand the nominal upkeep procedures related to the patterns of data upload to the satellites, changes in navigation parameter values at uploads, and handling of the system anomalies. The results are generally consistent with the technical data on GLONASS provided by the Soviets. C.D.

A93-21143
GPS/GLONASS FLIGHT TEST, LAB TEST AND COVERAGE ANALYSIS TESTS
RANDOLPH G. HARTMAN, MATS A. BRENNER, and NAGU M. KANT (Honeywell, Inc., Commercial Flight Systems Group, Minneapolis, MN) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 333-344. refs

The results of GPS/GLONASS combined system evaluation tests are presented. Navigation data from flights sampled worldwide are analyzed and the results are used to determine the relation between the WGS-84 and SGS-5 earth fixed coordinate systems. The consistency of the data is discussed, and the availability of the GLONASS satellites in relation to the almanac is evaluated. Integrity coverage results using future GPS and GLONASS constellation are also presented. C.D.

A93-21144
A DISTRIBUTED, MESSAGE-BASED, AIRSPACE ENVIRONMENT
GEORGE C. MCKINNEY and ALBERT W. BLACKBURN (Aero Systems Associates, Valley Forge, PA) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 345-362. refs

Illustrative examples are used to define a generic distributed airspace architecture. This new model for future airspace control depends on precise positioning, digital communications, and data processing. The three primary ingredients of the recommended architecture are (1) an airborne computer and associated data bases, (2) a digital computer-to-computer communications environment, and (3) a local precise navigation environment. It is shown that satellite navigation and digital communication can create an airspace information environment while airborne microprocesses provide synergies, synthetic vision, and moving map displays. C.D.

A93-21145
AIRPORT NAVIGATION AND SURVEILLANCE USING GPS AND ADS
H. R. PILLEY and LOIS V. PILLEY (DSDC, Deering, NH) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 363-371. refs

This paper describes the integration of GPS position reports with highly accurate 2D or 3D airport maps for cockpit navigation and ATC. Digital mapping techiques, map accuracies, coordinate systems, local monumentation, and Automatic Dependent Surveillance (ADS) techniques are examined. GPS receiver requirements and differential corrections are discussed. C.D.

A93-21147
PERFORMANCE ANALYSIS OF A MINIATURIZED AIRBORNE GPS RECEIVER
STEVEN L. PATTON, DAVID L. VAN DUSSELDORP, and REDGE G. BARTHOLOMEW (Rockwell International Corp., Cedar Rapids, IA) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 413-422. refs

A GPS receiver has been designed with 75 percent size

reduction and 67 percent weight reduction while maintaining high performance. The user will have accurate navigation over the full envelope of dynamics and jamming. The digital design contains features for future enhancement such as multitip correlators. The design aspects of the receiver, the equipment and methodologies used to measure and compare performance are described and performance data are presented. C.D.

A93-21152
DIFFERENTIAL GPS AUTONOMOUS FAILURE DETECTION
ALISON BROWN, JANET KING (NAVSYS Corp., Monument, CO), and JOSEPH SPALDING (USCG, R&D Center, Groton, CT) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 521-535. Research supported by USCG refs

A detection and isolation algorithm is described which allows Differential GPS (DGPS) errors to be detected autonomously in the GPS receiver. The design of the algorithm is presented along with simulation test results which demonstrate its ability to detect failure before the DGPS solution exceeds a 10 m threshold. C.D.

A93-21154* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ERRORS IN LONG DISTANCE KINEMATIC GPS
OSCAR L. COLOMBO (NASA, Goddard Space Flight Center, Greenbelt, MD) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 673-680. refs (Contract NAG5-245)

An attempt is made to quantify the contribution of tropospheric refraction, GPS ephemerides errors, and unresolved ambiguities to the overall error in the use of differential GPS to estimate aircraft position over very long distances. The extent to which such errors can be filtered out when estimating a trajectory, and how efficiently this may be done, are addressed. C.D.

A93-21155
UPDATE ON GPS INTEGRITY REQUIREMENTS OF THE RTCA MOPS
R. G. BROWN (Iowa State Univ. of Science and Technology, Ames), GERALD Y. CHIN, and JOHN H. KRAEMER (DOT, Volpe National Transportation Systems Center, Cambridge, MA) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 761-772. refs

A summary of the GPS integrity requirements as specified in the Minimum Operational Performance Standards (MOPS) is presented. Emphasis is given to the testing requirements as they pertain to Receiver Autonomous Integrity Monitoring (RAIM). Estimates for RAIM availability for various phases of flight and satellite configurations are presented. A new criterion for judging the quality of the satellite geometry for failure detection purposes is given. C.D.

A93-21157
WORK PERFORMED IN THE UNITED KINGDOM TO ESTABLISH THE FEASIBILITY OF RAIM IN A GPS RECEIVER IN FLIGHT
MICHAEL J. A. ASBURY (Civil Aviation Authority, London, United Kingdom), CHARLES S. DIXON, and ROLF JOHANNESSEN (BNR Europe, Ltd., Harlow, United Kingdom) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 789-799. Research supported by Civil Aviation Authority refs

Recent RAIM (Receiver Autonomous Integrity Monitoring) work done in the U.K. is reviewed. It is shown that barometric aiding of GPS improves the system by reducing the unavailability of RAIM from around 15 percent to around 1 percent. The sensitivity of these unavailabilities to accepted geometries is shown. Computer-modeled RAIM performance of a receiver in an aircraft whose dynamic profiles simulates flight along a specified track is examined. The false alarm rates and undetected error rates likely to be achieved are shown. C.D.

A93-21161
A NEW ALGORITHM OF RECEIVER AUTONOMOUS INTEGRITY MONITORING (RAIM) FOR GPS NAVIGATION
YANG GAO (Calgary Univ., Canada) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 887-896. refs

The existing RAIM algorithm is extended here to provide reliable and continuous navigation, and a new algorithm for GPS integrity monitoring is developed. In the new algorithm, classical statistics is used to detect and isolate possible failures and robust statistics is used to allow for the continuance of real-time navigation if the isolation procedure fails. It is demonstrated that the proposed RAIM algorithm can serve as either an independent algorithm of GPS integrity monitoring or as a complementary tool within the conventional RAIM algorithms. C.D.

A93-21162
STATISTICAL QUALITY CONTROL FOR KINEMATIC GPS POSITIONING
GANG LU (Calgary Univ., Canada) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 903-913. refs

A real-time statistical testing and implementation procedure for use in kinematic GPS positioning is presented. The method is based on the state space two-stage Kalman filter, hypothesis testing, and reliability analysis. The procedure is meant to detect, identify, and correct common biases such as cycle slips in carrier phases and outliers in phase rates and pseudoranges. The effectiveness of the procedure is verified using data collected in differential mode over a controlled traverse. C.D.

A93-21165
DECISION MAKING FOR A PUBLIC DIFFERENTIAL GPS SERVICE
ROBERT J. WILSON (USCG, Wildwood, NJ; U.S. Naval Postgraduate School, Monterey, CA) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 937-953. refs

The application of cost-effectiveness analysis to the Coast Guard's use of a nationwide Differential GPS (DGPS) is addressed. A way to quantify effectiveness is identified, and alternative system life cycle costs are estimated. DGPS performance is quantified with regard to accuracy, availability, coverage, integrity, and adaptability. A preliminary preference for a radio beacon transmission over a dedicated satellite channel is found based on user equipment prices. C.D.

A93-21167
GPS CONTINUITY - INITIAL FINDINGS
JEAN M. DURAND and THIERRY M. CARLIER (CNES, Toulouse, France) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 971-980. refs

This paper refines the definition of continuity, and positions it in relation to reliability, availability, integrity and the false alarm rate. It proposes a methodology for determining continuity losses of the GPS system due to unexpected space segment failures. It applies the methodology to the case of a navigator using the

GPS system during a non-precision approach with a 21- or 24-satellite constellation, possibly supplemented by a geostationary satellite. The paper discusses the initial findings, compares them with the continuity requirements currently being drafted by the civil aviation standards organizations, and deduces the availability which navigators can expect of GPS. It distinguishes between use of GPS as a supplemental means navigation system and use of GPS as a sole means navigation system. It discusses the influence of the SATZAP and GPS Integrity Channel (GIC) concepts.
Author

A93-21176
INSTITUTE OF NAVIGATION, NATIONAL TECHNICAL MEETING, SAN DIEGO, CA, JAN. 27-29, 1992, PROCEEDINGS
Washington Institute of Navigation 1992 448 p.

The present conference discusses the velocity accuracy of an integrated GPS/INS system, GPS/INS for the Advanced Interdiction Weapon System, planning for complementary MLS/GPS operations, GPS availability and reliability for aircraft precision approaches, GPS/Glonass carrier-phase operation, the Pacific engineering trials of an Automatic Dependent Surveillance system, and terminal area surveillance using GPS. Also discussed are the Navigation Sensor System Interface, an innovative sensor for inertial attitude measurement using the MHD principle, an integrated Soviet VLF/Omega receiver design, DGPS for space and return, a highly fault-tolerant dual inertial integrated navigation system, development status of the FAA testbed for wide-area differential GPS, data reduction and sensor fusion for GPS, and the geometry of GPS solutions. (For individual items see A93-21177 to A93-21204)
O.C.

A93-21178
INS/DGPS INTEGRATION FOR TRAJECTORY DETERMINATION OF A TEST VEHICLE
PIERRE E. POMMELLET and BERNARD PANEFIEU (Lab. de Recherches Balistiques et Aerodynamiques, Vernon, France) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 23-30. refs

A test vehicle has been devised for the operational evaluation of land-navigation systems. Attention is given to the onboard integration of an INS unit and a GPS receiver for calculation of reference trajectories. This integration is accomplished via Kalman smoother which estimates the positions, velocities, and attitudes of the vehicle in the course of signal postprocessing. System performance has been estimated to be of the order of 3-10 m in position, 0.05 m/sec in velocity, and better than 2 mrad in attitude.
O.C.

A93-21180
PLANNING FOR COMPLEMENTARY MLS/GPS OPERATIONS
KAREN L. BURCHAM (FAA, MLS Program Office, Washington) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 39-45. refs

The FAA and the U.S. aviation industry are developing and implementing techniques and infrastructures for the support of fully integrated MLS and GPS operations. Attention is presently given to the application of complementary MLS/GPS capabilities to the ranging function that is entailed in curved/segmented approaches; this application promises to be able to reduce functional redundancies in the U.S. airspace system, while accomplishing a seamless transition from en route guidance, to terminal area guidance, to precision approach guidance.
O.C.

A93-21181
MIAS, THE INTEGRATION OF MLS WITH DGPS/DLORAN-C
DURK VAN WILLIGEN and ELSO P. M. VLIETSTRA (Delft Univ. of Technology, Netherlands) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 47-55. refs

The MLS-Integrated Approach System (MIAS) proposed, which is a hybridization of the MLS with DGPS and DLoran-C, yields full 3D guidance during the approach phase of flight; it also results in greater GPS and Loran-C integrity. The along-track error rate is reduced from 30 m to less than 10 m. In addition, the cooperation of two fully independent localization devices in MIAS improves reliability, availability, and integrity. Where DGPS is available, the height and along-track errors are respectively reduced to less than 2 and 10 m.
O.C.

A93-21182
GPS AVAILABILITY AND RELIABILITY FOR AIRCRAFT PRECISION APPROACH
PAUL N. CREAMER, E. M. GEYER, and JOSEPH J. PISANO (Analytic Sciences Corp., Reading, MA) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 57-66. Research supported by FAA refs

A comparison of selected requirements for a satellite-based precision-approach system with the projected performance of GPS in the unenhanced and enhanced configurations has indicated that the projected ranging accuracy of GPS using carrier-smoothed code-processing is insufficient for support of Category II or III operations. The DOD-furnished baseline GPS constellation will fail to provide Category I accuracy for over 3 hr/day; this level of unavailability is unacceptable for a general-use system. Even a 48-satellite constellation will not meet the recommended availability requirements.
O.C.

A93-21183* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYSIS OF DGPS/INS AND MLS/INS FINAL APPROACH NAVIGATION ERRORS AND CONTROL PERFORMANCE DATA
RICHARD M. HUESCHEN and CARY R. SPITZER (NASA, Langley Research Center, Hampton, VA) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 67-77. refs

Flight tests were conducted jointly by NASA Langley Research Center and Honeywell, Inc., on a B-737 research aircraft to record a data base for evaluating the performance of a differential DGPS/inertial navigation system (INS) which used GPS Course/Acquisition code receivers. Estimates from the DGPS/INS and a Microwave Landing System (MLS)/INS, and various aircraft parameter data were recorded in real time aboard the aircraft while flying along the final approach path to landing. This paper presents the mean and standard deviation of the DGPS/INS and MLS/INS navigation position errors computed relative to the laser tracker system and of the difference between the DGPS/INS and MLS/INS velocity estimates. RMS errors are presented for DGPS/INS and MLS/INS guidance errors (localizer and glideslope). The mean navigation position errors and standard deviation of the x position coordinate of the DGPS/INS and MLS/INS systems were found to be of similar magnitude while the standard deviation of the y and z position coordinate errors were significantly larger for DGPS/INS compared to MLS/INS.
Author

A93-21184
GUIDELINES FOR NAVSTAR GPS EMBEDDED RECEIVER APPLICATIONS
DONALD LATTERMAN, EDDY EMILE, and C. A. WU (USAF, Space Systems Div., Los Angeles AFB, CA) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 81-88. refs

The embedding of a GPS receiver in a host avionics system is noted to yield significant advantages over a stand-alone receiver in certain specialized applications, such as communications, training, and missile guidance. The NAVSTAR GPS Joint Program Office is developing guidelines for such embedded systems' application. Prospective DOD GPS receiver designs will be strongly influenced by the potentially large commercial market for GPS applications.
O.C.

A93-21186
ON THE SELECTION OF A GPS VALIDITY INDICATOR FOR AIRCRAFT NAVIGATION IN THE NATIONAL AIRSPACE SYSTEM (NAS)
DIRK DEDOES, LAWRENCE LUPASH, KENNETH RHOADES (Intermetrics, Inc., Huntington Beach, CA), and JACQUES BESER (JB Systems, Laguna Hills, CA) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 147-157. refs

This paper identifies and evaluates two potential warning indicators and presents test data generated for a representative flight path, using a multichannel GPS signal generator and a Phase III airborne 5 channel receiver (RCVR3A). The scenario includes a wide range of satellite geometry DOPS and measurement errors. Statistical post processing, including regression analysis and confidence interval determination are then used to yield threshold values for each indicator and for each flight mode. In addition, the robustness of the indicator in the presence of GPS system anomalies is assessed. Finally, conclusions are drawn and a recommendation is made for a GPS Validity Indicator for aircraft operations in the national airspace system. Author

A93-21188
THE APPLICATIONS, BENEFITS, AND ISSUES OF EMPLOYING GPS AND GLONASS WITH AUTOMATIC DEPENDENT SURVEILLANCE
KEITH D. MCDONALD, JAMES NUSSBAUM (Sat Tech Systems, Inc., Arlington, VA), and WILLIAM BADURKA (MiTech, Inc., Washington) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 179-187. refs

Automatic dependent surveillance (ADS) uses a digital link to automatically transmit 3D aircraft position data to air-traffic controllers, either automatically or upon request. The improved navigation accuracy of GPS and Glonass can potentially improve navigational system accuracies by orders of magnitude. GPS navigation data obtained by ocean-crossing aircraft, and transmitted to the ground automatically by ADS, may yield substantial benefits. O.C.

A93-21190
TERMINAL AREA SURVEILLANCE USING GPS
H. R. PILLEY and LOIS V. PILLEY (Deering System Design Consultants, Inc., NH) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 195-203. Research supported by FAA refs

An account is given of the integration of GPS position reports with highly accurate, 2D or 3D airport maps for cockpit navigation and ATC. Real-time GPS position updates displayed on the map clearly identify the position of the aircraft on the airport surface, while waypoints and travel paths identify the routes to and from the gate. The same system, when coupled with an RF-compatible X.25 data-link, can furnish the aircraft's identifier, position, and speed to either ATC or other aircraft. Attention is given to demonstrated automatic dependent surveillance techniques and GPS receiver requirements. O.C.

A93-21192
AUTOMATIC DEPENDENT SURVEILLANCE CAPACITY OF A GEOSTATIONARY SATELLITE SYSTEM IN THE U.S. DOMESTIC AIRSPACE
CURTIS A. SHIVELY (Mitre Corp., McLean, VA) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 215-222. refs

In satellite-based Automatic Dependent Surveillance (ADS), an aircraft's position derived by an on-board navigation system is relayed via satellite to air traffic control (ATC) systems on the ground. Standards are being developed by the International Civil Aviation Organization (ICAO) for an Aeronautical Mobile-Satellite Service (AMSS) which would include ADS. The AMSS satellite link is being designed to be a subnetwork of the Aeronautical Telecommunications Network (ATN). A satellite communications system that could provide AMSS ADS in the U.S. domestic airspace is being constructed by the American Mobile Satellite Corporation (AMSC). This paper describes a preliminary analysis of the AMSC first generation system capacity (number of aircraft) for AMSS ADS in the early part of the 21st century. Capacity is related to the required spectral bandwidth as a function of: (1) ADS update interval, (2) communications scheme, (3) spectral efficiencies of different modulation techniques, and (4) the amount of overhead associated with the ATN. Author

A93-21197
AN MLS FOR THE TWENTY-FIRST CENTURY
HERBERT P. RAABE *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 303-310. refs

In the present MLS concept, a C-band microwave radiation field is generated around an airport over 360 deg in azimuth and 20 deg in elevation, to a distance of 30 nautical miles, by a rotating fan beam scanner that also furnishes distance measurements; a unique signature is thereby generated from which aircraft positions can be derived. For precision landing guidance, the scanner also generates an identical signature in Ku-band over an azimuth of 120 deg and provides hemispherical coverage over short distances to serve both VTOL aircraft and taxiing aircraft in the airport. O.C.

A93-21198
INTEGRATED SOVIET VLF/OMEGA RECEIVER DESIGN
BENJAMIN PETERSON, KEITH GROSS, ERIC CHAMBERLIN, and TIMOTHY MONTAGUE (U.S. Coast Guard Academy, New London, CT) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 311-318. Previously announced in STAR as N92-33809 Research supported by USCG refs

With recent statements from Russian officials indicating their very long frequency (VLF) navigation system may be operated in the future for worldwide civil use, its potential use in conjunction with the existing Omega system is of renewed interest. The design of an Integrated Russian VLF/Omega Receiver implemented on a Texas Instruments TMS320C25 microprocessor based Ariel DSP 16 plug-in board installed in a PC-compatible portable computer is presented. The system also requires an external antenna, pre-amp, and frequency reference. The DSP16 board digitizes the radio frequency (RF) signal to 16 bits and then digitally mixes with the sines and cosines of the three Soviet frequencies plus 10.2, 11 1/3, and 13.6 kHz. The mixer outputs are lowpass filtered and the comb filters implemented for the respective epochs. The PC compatible computer accesses and processes the comb filter outputs, calculating and logging signal phase and amplitude. The design allows for each future expansion to include unique and VLF communications frequencies. Author

A93-21199
A STATISTICAL COMPARISON OF DIFFERENTIAL GPS AND LASER GENERATED TIME, SPACE POSITIONING INFORMATION FOR AIRCRAFT FLIGHT TESTING
ALAN LAWER (USAF, Space Systems Div., Los Angeles AFB, CA), DIRK DEDOES, and RON GRAY (Intermetrics, Inc., Huntington Beach, CA) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 329-335. refs

Results are presented from a study which evaluated the accuracy of a differential-GPS (DGPS) system employing Phase III GPS receivers through comparisons with laser-generated Time, Space, and Position Information (TSPI). Data obtained from C-141 and T-39 flights with low-to-moderate dynamics were processed to evaluate DGPS TSPI accuracy. Results comparable to those of LTSPI were obtained for vehicle positions, but without the need for calibration. O.C.

A93-21201
DIFFERENTIAL GPS CONTROL OF STARCAR 2
STEVEN C. CROW and FRANK L. MANNING (Arizona Univ., Tucson) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 359-377. Research supported by Univ. of Arizona refs

This paper assesses the ability of the Navstar Global Positioning System to guide a robotic vehicle with precision. To secure accurate positional estimates, we use differential GPS positions and Doppler velocities, combined in a filter that exploits the high accuracy of velocity data. A model of vehicle dynamics overcomes a time lag of GPS fixes, which amounts to 1.5 sec even for an advanced six-channel sensor. The system attains positional accuracies around 1 m along each horizontal axis with no changes of satellites and 2 m over long periods. The system is able to steer a car around a 400-m track so accurately that the laps merge into common pixels on a video display. Author

A93-21525 National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
VISION-BASED RANGE ESTIMATION USING HELICOPTER FLIGHT DATA
PHILLIP N. SMITH, BANAVAR SRIDHAR, and BASSAM HUSSIEN, (NASA, Ames Research Center, Moffett Field, CA) Jun. 1992 8 p. IEEE Computer Society Conference on Computer Vision and Pattern Recognition, Champaign, IL, June 15-18, 1992, Paper Previously announced in STAR as N92-32424 refs
(Contract RTOP 505-64-36)
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Pilot aiding during low-altitude flight depends on the ability to detect and locate obstacles near the helicopter's intended flightpath. Computer-vision-based methods provide one general approach for obstacle detection and range estimation. Several algorithms have been developed for this purpose, but have not been tested with actual flight data. This paper presents results obtained using helicopter flight data with a feature-based range estimation algorithm. A method for recursively estimating range using a Kalman filter with a monocular sequence of images and knowledge of the camera's motion is described. The helicopter flight experiment and four resulting datasets are discussed. Finally the performance of the range estimation algorithm is explored in detail based on comparison of the range estimates with true range measurements collected during the flight experiment. Author

A93-21630
AIRSPACE REDESIGN - MAKING THE GRADE
JOSEPH DEL BALZO (FAA, Washington) Aerospace America (ISSN 0740-722X) vol. 31, no. 1 Jan. 1993 p. 38-41.
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With enhanced computer graphics and better approaches to handling data, new software improves FAA's airspace design capabilities. This paper describes a new software, called Graphical Airspace Design Environment (GRADE), currently in use by the FAA to improve and expedite its airspace design capability. Simple to operate and highly customized, GRADE is a CAD tool that correlates the recorded radar flight track data with a complex set of airspace, airway, and navigational information. R.E.P.

A93-21822
ANALYSIS OF A HIGH-PERFORMANCE C/A-CODE GPS RECEIVER IN KINEMATIC MODE
M. E. CANNON and G. LACHAPELLE (Calgary Univ., Canada) Navigation (ISSN 0028-1522) vol. 39, no. 3 Fall 1992 p. 285-300. refs
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Results are presented of a land semikinematic or stop-and-go test, performed under normal operational conditions to assess the conduct of a high-accuracy and multipath-resistant new C/A receiver technique. This test-type was selected to provide an accurate assessment of both the code data and carrier phase under kinematic and static conditions. The control points determined with the phase data are in agreement at the centimeter level with the values obtained by a conventional GPS survey. R.E.P.

A93-21823
A BASELINE GPS RAIM SCHEME AND A NOTE ON THE EQUIVALENCE OF THREE RAIM METHODS
R. G. BROWN (Iowa State Univ. of Science and Technology, Ames) Navigation (ISSN 0028-1522) vol. 39, no. 3 Fall 1992 p. 301-316. Research supported by DOT refs
Copyright

A baseline RAIM scheme is proposed that can serve as a standard for performance comparisons. This scheme is based on a unified theory which states that under the condition of equal alarm rates, the range comparison, least-squares-residuals, and parity RAIM techniques all give identical results. This method is a straightforward, workable RAIM technique that is easily understood. R.E.P.

A93-21824
EFFECT OF TERRAIN MASKING ON GPS POSITION DILUTION OF PRECISION
T. E. DUERR (Johns Hopkins Univ., Laurel, MD) Navigation (ISSN 0028-1522) vol. 39, no. 3 Fall 1992 p. 317-323. refs
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An analysis of position dilution of precision (PDOP) for a GPS receiver in an idealized valley is presented. It is demonstrated that PDOP varies significantly with time of day, can be large for a substantial part of a one day period, and is a strong function of latitude. The results characterize GPS receiver operation relevant to aircraft at low altitudes, land vehicles, and some precision guided missiles. R.E.P.

A93-22275
TRACK MOVING EMITTERS WITH KALMAN PROCESSING
RAYMOND H. BURROS Microwaves & RF (ISSN 0745-2993) vol. 31, no. 12 Dec. 1992 p. 83, 84, 86.
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Receivers based on the Kalman filter technique are capable of locating slow-moving targets from a constant speed platform. The moving-emitter Kalman-filter algorithm uses prior knowledge along with new empirical data to give a definite output at each computation. O.G.

N93-15988# Naval Postgraduate School, Monterey, CA.
CORRECTION OF INERTIAL MEASUREMENTS USING GPS UPDATES FOR UNDERWATER NAVIGATION M.S. Thesis
STEVE NAGENGAST Sep. 1992 104 p
(AD-A257329) Avail: CASI HC A06/MF A02

An Autonomous Underwater Vehicle (AUV) can combine a Global Positioning System (GPS) receiver with an Inertial Navigation System (INS) to navigate with a specified accuracy level. The AUV would be required to surface periodically to obtain a GPS fix. A computer simulation has been developed using an AUV model and an INS error model to generate noisy measurements. A Kalman filter is used to estimate the simulated INS errors. Several runs were executed to compare combinations of equipment with different levels of accuracy. GRA

N93-16213# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.
TERMINAL AREA TRAFFIC MANAGEMENT
H. G. VISSER Jun. 1992 67 p
(LR-684; ETN-92-92878) Avail: CASI HC A04/MF A01

Time based traffic management procedures that were proposed to increase the capacity of the air traffic system by the beginning of the next century are considered. Today's air traffic control systems are described. Their shortcomings are identified and the need for improved systems and procedures is discussed. The new technologies which will enable the limitations of the present communication, navigation and surveillance systems to be overcome by providing higher quality and improved efficiency, are discussed. Because terminal area management is certainly one of

the most critical aspects of overall air traffic management, the main focus is on this issue. Current research efforts towards improved trajectory optimization and control for flight operations in an extended terminal area are described. ESA

N93-16343# National Aerospace Lab., Amsterdam (Netherlands). Flight Div.
DME-DERIVED POSITIONS COMPARED WITH MLS- AND ILS-DERIVED POSITIONS
P. J. HOOGEBOOM Mar. 1990 38 p Sponsored by Dept. of Civil Aviation
(NLR-TP-90119-U; ETN-93-92859) Avail: CASI HC A03/MF A01

From Distance Measurement Equipment (DME) data recorded during Microwave Landing System (MLS) flight trials, the positions of the aircraft was determined by postprocessing and compared with the MLS and Instrument Landing System (ILS) derived positions. An empirical determination of the expected accuracy of a rho-rho DME solution is reported. The difference between the DME position and the MLS (or ILS) position is presented. The predicted DME position error deviates slightly from the data analysis results. The main characteristics of the model was reflected by the results at an intersection angle between the distances of about 30 degrees. The position error is about four times larger than at an intersection angle of 90 degrees. When using a rho-rho DME position solution to navigate in the vicinity of an airfield at low altitudes, reliability problems with the used DME distances can be experienced due to line of sight problems. Depending on the intersection angle between the distances, the position determination error will be in the order of 500 to 1000 m. Compared with an MLS derived position, the DME position error is at least an order of magnitude larger. ESA

N93-16498# Federal Aviation Administration, Atlantic City, NJ.
THE EFFECT OF TCAS INTERROGATIONS ON THE CHICAGO O'HARE ATCRBS SYSTEM Final Report, 5-6 May and 20-23 Jul. 1992
LEO WAPELHORST, THOMAS PAGANO, and JOHN VANDONGEN Nov. 1992 42 p
(DOT/FAA/CT-92/22) Avail: CASI HC A03/MF A01

This report documents the Federal Aviation Administration (FAA) data collection and analysis effort to investigate Secondary Surveillance Radar (SSR) problems encountered at the Chicago O'Hare Terminal Approach Control (TRACON) facility. The FAA has mandated the implementation of Traffic Alert and Collision Avoidance System (TCAS) II to the entire air transport fleet by December 31, 1993. To provide for the smooth and orderly implementation of TCAS II, the TCAS Transition Program has been established to accomplish these objectives. The FAA Technical Center Research Directorate for Aviation Technology, ACD-320, conducted the investigation by developing the data collection system capability of the Data Link Test and Analysis System (DATAS). Two distinct capabilities were developed to monitor the uplink and downlink activity of the SSR system frequencies. The uplink data collection system is an airborne installation of Digital Link Test and Analysis Systems (DATAS) on an FAA aircraft and test flights were conducted to obtain the uplink data. The downlink data collection system was installed at the ground radar facility to monitor the Air Traffic Control Radar Beacon System (ATCRBS) receiver signal for downlink analysis. Data results and analysis of both efforts are documented herein. Author

N93-16692*# Vigyan Research Associates, Inc., Hampton, VA.
PILOT WEATHER ADVISOR
W. A. KILGORE, S. SETH, N. L. CRABILL (Aero Space Consultants, Newport News, VA.), S. T. SHIPLEY (Hughes STX, Inc., Lanham, MD.), I. GRAFFMAN (Hughes STX, Inc., Lanham, MD.), and J. ONEILL (NIALL Enterprises, Belmont, WI.) Nov. 1992 43 p
(Contract NAS1-19250; RTOP 324-01-00)
(NASA-CR-189723; NAS 1.26:189723) Avail: CASI HC A03/MF A01

The results of the work performed by ViGYAN, Inc., to demonstrate the Pilot Weather Advisor cockpit weather data system using a broadcast satellite communication system are presented. The Pilot Weather Advisor demonstrated that the technical problems involved with transmitting significant amount of weather data to an aircraft in-flight or on-the-ground via satellite are solvable with today's technology. The Pilot Weather Advisor appears to be a viable solution for providing accurate and timely weather information for general aviation aircraft. Author

N93-16841# Federal Aviation Administration, Atlantic City, NJ.
RESULTS OF DATAS INVESTIGATION OF ILLEGAL MODE S ID'S AT JFK AIRPORT Final Report, 25 Aug. - 29 Sep. 1992
THOMAS PAGANO, JOHN VANDONGEN, and LEO WAPELHORST Dec. 1992 18 p
(DOT/FAA/CT-92/26) Avail: CASI HC A03/MF A01

This report documents the second deployment of the Data Link Test and Analysis System (DATAS) as a Traffic Alert and Collision System (TCAS) monitor. The purpose was to identify aircraft which were reporting Illegal Mode Select (Mode S) ID's. The project was conducted by the Research Directorate for Aviation Technology, Airborne Collision Avoidance & Data systems Branch, Federal Aviation Administration (FAA) Technical Center. Author

N93-17311*# Berry Coll., Mount Berry, GA. Dept. of Physics.
MULTIPATH EFFECTS IN A GLOBAL POSITIONING SATELLITE SYSTEM RECEIVER
MALCOLM W. MCDONALD *In* Alabama Univ., 1992 NASA/ASEE Summer Faculty Fellowship Program 4 p Dec. 1992
Avail: CASI HC A01/MF A03

This study, as a part of a large continuing investigation being conducted by the Communications Systems Branch of the Information and Electronic Systems Laboratory at the Marshall Space Flight Center, was undertaken to explore the multipath response characteristics of a particular Global Positioning Satellite (GPS) receiver which was available in the laboratory at the beginning and throughout the entirety of the study, and to develop a suitable regime of experimental procedure which can be applied to other state-of-the-art GPS receivers in the larger investigation. Author

N93-17559# National Aerospace Lab., Amsterdam (Netherlands). Informatics Div.
NAVSTAR GLOBAL POSITIONING SYSTEM: INTRODUCTION AND STATUS
O. B. M. PIETERSEN 25 Jan. 1991 13 p Presented at NERG Meeting on Satellite Navigation, Amsterdam, Netherlands, 6 Nov. 1991
(NLR-TP-91008-U; ETN-92-92511) Avail: CASI HC A03/MF A01

A general description of the Navstar Global Positioning System (GPS), a space based radio positioning system which provides suitably equipped users with highly accurate position, velocity, and time data, is given. The technical characteristics of the space segment, control segment, and user segment are described. The status of the three segments is given as existing at the end of 1990. The system performance and GPS satellite signals are discussed. ESA

N93-17584# Technische Univ., Delft (Netherlands).
CARRIER WAVE SIGNALS INTERFERING WITH LORAN-C Ph.D. Thesis
MARTIN BECKMANN 1992 167 p
(ETN-92-92528) Avail: CASI HC A08/MF A02

The interference problems on the Loran C radio navigation system is analyzed. The problems and a description of the effects of interference in Loran C are discussed. The description fills a gap in the numerical analysis of the influence of interference on Loran C. It shows that for further expansion of Loran C especially in western Europe, solutions to the interference problems are needed. Two types of interference to Loran C are distinguished and their effects on positioning are described. The attention is also focused on interference from nonLoran C transmissions in the frequency bands around the Loran C spectrum. This type of interference can be attacked at two levels: in the Loran C system by properly choosing system parameters, and in Loran C receivers by including all kinds of filtering techniques to remove the unwanted

signals. For both levels, methods for interference reduction have been developed. It is shown that the largest problem is the proper detection of harmful interference signals, while rejection of signals is relatively easy with todays technology. A new concept for detecting all interference harmful to a Loran C chain, based on digital signal processing of antenna signals with very powerful processors, is presented. ESA

N93-17954# National Aerospace Lab., Amsterdam (Netherlands). Flight Div.
NARSIM AND EFMS: TOOLS FOR RESEARCH ON INTEGRATED ATM
W. DENBRAVEN and A. L. C. VANDORP 1989 66 p Presented at Symposium on Man-Machine Interface Aspects in Civil Aviation, Delft, Netherlands, 8 Dec. 1989
(NLR-TP-89336-U; ETN-93-93318) Avail: CASI HC A04/MF A01

An overview of Air Traffic Management (ATM) research is given and the NLR Air Traffic control Research Simulator (NARSIM) and the Experimental Flight Management System (EFMS), are described. The overview of ATM research includes a general description of ATM, past ATM studies, international research programs, the NLR activities in the field of ATM, and a methodology for research in the future ATM man machine system. The description of NARSIM comprises details of present day automation in air traffic control, a functional description of NARSIM, a description of the NARSIM work environment, hardware configuration and controller workstations, and an introduction on the main research areas related to the ATM man machine system. The description of EFMS comprises an overview of the capabilities and functions of currently common flight management systems, some remarks on the pilots' general opinon on FMS usage, the EFMS project, including a description of EFMS components identified for common development, and a brief overview of the application of EFMS at the NLR. NARSIM and EFMS will enable research in most of the research areas related to the future ATM man machine system, covering both the aspects of man machine task division and man machine communication. ESA

N93-18202# Federal Aviation Administration, Washington, DC. Office of Airport Planning and Programming.
REPORT TO CONGRESS: LONG-TERM AVAILABILITY OF ADEQUATE AIRPORT SYSTEM CAPACITY
Jun. 1992 29 p
(AD-A258209; DOT/FAA/PP-92-4) Avail: CASI HC A03/MF A01

Report is submitted in accordance with Section 309 of the Airport and Airway Safety and Capacity Expansion Act of 1987, which requires the Secretary of Transportation to conduct a study for the purpose of developing an overall airport system plan through the year 2010. The report describes the probably extent of airport congestion in the future, given current trends. GRA

N93-18309# Naval Postgraduate School, Monterey, CA.
AUTOMATIC PULSE SHAPING WITH THE AN/FPN-42 AND AN/FPN-44A LORAN-C TRANSMITTERS M.S. Thesis
DEAN C. BRUCKNER Dec. 1992 199 p
(AD-A257860) Avail: CASI HC A09/MF A03

Automatic pulse shape control is simulated for the N/FPN-42 and AN/FPN-44A tube type transmitters. A linear, time invariant (LTI) pole-zero model is developed for each transmitter at a typical operating point using the least squares modified Yule-Walker method and Shank's method. LTI models for a range of operating points are catenated to represent observed nonlinear behavior, and observed time variations are added. After these combined models are tested, a linear controller based on the method of steepest descent is implemented. These models, the control algorithm, and transmitter system details such as power supply droop, dual rating, and noise are then incorporated into a MATLAB simulation program. In a variety of realistic tests, the control algorithm successfully shaped the Loran-C pulse, except that zero-crossing times were not always in tolerance, and the algorithm showed a sensitivity to noise. The algorithm controlled Envelope-to-Cycle Difference, produced an entire Phase Code Interval of pulses while compensating for droop and phase code bounce, and produced a near-optimal transmitter drive waveform for the transmitter/antenna system using the dummy load. GRA

N93-18873*# Ohio Univ., Athens. Avionics Engineering Center.
GPS INTERFEROMETRY Semiannual Progress Report, 1 Apr. - 30 Sep. 1992
FRANK VANGRASS 1992 14 p
(Contract NAG1-1423)
(NASA-CR-192301; NAS 1.26:192301) Avail: CASI HC A03/MF A01

This semi-annual progress report provides an overview of the work performed during the first six months of Grant NAG 1 1423, titled 'GPS Interferometry'. The Global Positioning System (GPS) is a satellite-based positioning and timing system. Through the use of interferometric processing techniques, it is feasible to obtain sub-decimeter position accuracies for an aircraft in flight. The proposed duration of this Grant is three years. During the first year of the Grant, the efforts are focussed on two topics: (1) continued development of GPS Interferometry core technology; and (2) rapid technology demonstration of GPS interferometry through the design and implementation of a flight reference/autoland system. Multipath error has been the emphasis of the continued development of GPS Interferometry core technology. The results have been documented in a Doctoral Dissertation and a conference paper. The design and implementation of the flight reference/autoland system is nearing completion. The remainder of this progress report summarizes the architecture of this system. Author

N93-18927# Federal Aviation Administration, Washington, DC. Office of Aviation Medicine.
EN ROUTE AIR TRAFFIC CONTROLLERS USE OF FLIGHT PROGRESS STRIPS: A GRAPH-THEORETIC ANALYSIS Final Report
O. U. VORTAC, MARK B. EDWARDS, JUDI P. JONES, CAROL A. MANNING, and A. J. ROTTER Nov. 1992 18 p
(Contract DTFA02-91-C-9108)
(AD-A259062; DOT/FAA/AM-92/31) Avail: CASI HC A03/MF A01

In the United States, flight data are represented on a paper Flight Progress Strip (FPS). The role of the FPS has recently attracted attention because of plans to automate this aspect of air traffic control. The communication activities and FPS activities of air traffic controllers were categorized while they controlled air traffic of varying complexity. Transition networks were derived from the empirical transitions. These networks indicated that several aspects of air traffic control generalize across complexity, including the centrality of writing-on-the-FPS's to the control of traffic. Complexity was a factor when FPS's were used with high complexity traffic situations, requiring the controller to direct uninterrupted periods of time to the management of the FPS's rather than integrating these board management responsibilities with the responsibilities of separating aircraft. GRA

N93-18951# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
DETECTION OF SPOOFING, JAMMING, OR FAILURE OF A GLOBAL POSITIONING SYSTEM (GPS) M.S. Thesis
JUAN R. VASQUEZ 4 Dec. 1992 177 p
(AD-A259023; AFIT/GE/ENG/92D-37) Avail: CASI HC A09/MF A02

The Air Force has equipped its aircraft with avionic systems such as Global Positioning System (GPS) and Inertial Guidance Systems (INS) capable of providing accurate navigation solutions. The aircrews flying these aircraft require a system that can either survive the hostile environments encountered in combat or notify the aircrew that their performance has been significantly degraded. Failure detection and isolation techniques using an extended Kalman filter and generalized likelihood ratios using matched filters are studied. Analysis is conducted using a Kalman filter development package known as the Multimode Simulation for Optimal Filter Evaluation (MSOFE). Both a large order truth model

for the navigation system (in which a full 24 satellite constellation is modeled) and a reduced-order Kalman filter are developed. Results suggest that failures within the GPS can be detected, isolated, and in some cases compensated through feedback.
GRA

N93-19067# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
A MODEL OF GLOBAL POSITIONING SYSTEM (GPS) MASTER CONTROL STATION (MCS) OPERATIONS M.S. Thesis
DAVID N. KOSTER 15 Dec. 1992 210 p
(AD-A258846; AFIT/GSO/ENS/92D-9) Avail: CASI HC A10/MF A03

The United States Air Force's Navstar Global Positioning System (GPS) provides high-accuracy space-based navigation and time distribution to suitably-equipped military and civilian users. The system consists of earth-orbiting satellites and a world-wide network of ground stations. A single operational control center, the GPS Master Control Station (MCS) monitors, maintains, and commands the GPS satellite constellation. The on-going deployment of the complete satellite constellation and recent changes in the operational crew structure may invalidate previously used planning and management paradigms. There is currently no analytical method for predicting the impact of these and other environmental changes on system parameters and performance. Extensive testing cannot be performed at the MCS itself due to the criticality of the GPS mission and lack of operational redundancy. A discrete event simulation model of the MCS operations center task flow, focusing on the creation and testing of a sliding-window MCS activity scheduler, is provided and validated. The simulation was validated using MCS historical data. Experiments were conducted by varying the number of ground stations and satellite constellation size available to the simulation. The results, while not quantitatively trustworthy, were used to draw general conclusions about the GPS operational environment.
GRA

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AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

A93-17714
TECHNOLOGICAL CHALLENGES WITH SMART STRUCTURES IN GERMAN AIRCRAFT INDUSTRY
CHR. BOLLER, H. HOENLINGER, and O. SENSBURG (MBB GmbH, Munich, Germany) *In* European Conference on Smart Structures and Materials, 1st, Glasgow, United Kingdom, May 12-14, 1992, Proceedings Orsay, France/Bellingham, WA/Bristol, United Kingdom European Optical Society/Society of Photo-Optical Instrumentation Engineers/Institute of Physics 1992 p. 289-292. refs
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Application of smart structures in aircraft industry is reviewed focusing on structure health monitoring and active structures. It is concluded that modern structure health monitoring systems are capable of considerably reducing maintenance and repair costs. The introduction of multifunctional structures (higher strength radoms or load carrying access doors) will also contribute to lighter airplane design. Active control technologies in conjunction with aeroelastic tailoring, structural stiffness and damping combined with smart materials which change their properties in a controlled manner in the design process will make it possible to obtain much lighter structures.
O.G.

A93-17728
ADAPTIVE/CONFORMAL WING DESIGN FOR FUTURE AIRCRAFT
F. AUSTIN, G. J. KNOWLES, W. G. JUNG, C. C. TUNG, and E. M. SHEEDY (Grumman Corporate Research Center, Bethpage, NY) *In* European Conference on Smart Structures and Materials, 1st, Glasgow, United Kingdom, May 12-14, 1992, Proceedings Orsay, France/Bellingham, WA/Bristol, United Kingdom European Optical Society/Society for Photo-Optical Instrumentation Engineers/Institute of Physics 1992 p. 387-390. refs
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We discuss the design and analysis of an actuator system to deform a wing over its entire cross section so that optimum aerodynamic shapes can be realized for more than one flight condition. Preliminary aerodynamic analyses indicate that this concept could reduce the drag coefficient of the JSTARS wing by at least 6 percent during loiter; however, aerodynamic design optimization is required to quantify the improvement. A test model of an active rib is being constructed. Finite-element analysis of this model indicates that the system will accurately produce desired deformed shapes.
Author

A93-18330
REFINEMENT OF ALGORITHMS FOR CALCULATING THE REMAINING LIFE FROM MAGNETIC RECORDING INSTRUMENT DATA [UTOCHNENIE ALGORITMOV RASCHETA RASKHODA USTALOSTNOGO RESURSA PO ZAPISIAM MSRP]
N. M. KIMLIK, IU. M. PARAMONOV, and M. L. SKRIPKA *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 15-18. In Russian.
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A solution is presented for the problem of updating an algorithm for calculating the remaining life of the IL-86 aircraft wing. The relevant parameters are estimated from the results of fatigue tests simulating the loading conditions characteristic of a typical flight. The parameter estimates are found to be strongly dependent on the initial model, whereas the predicted life is practically the same for different models.
V.L.

A93-18331
JUSTIFICATION FOR THE LINEAR RECORDING OF FATIGUE DAMAGE SUMMATION FOR AIRCRAFT STRUCTURES UNDER OPERATING CONDITIONS [K OBOSNOVANIIU LINEINOI FORMY ZAPISI SUMMIROVANIIA USTALOSTNOGO POVREZHDENIIA AVIAKONSTRUKTSII V USLOVIIAKH EKSPLUATATSII]
G. S. LOTSMANOV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 19-23. In Russian. refs
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The linear recording of damage summation is justified by the independence of the number of loading cycles and the intensity of fatigue damage accumulation, even though the physical processes can be nonlinear. The loading conditions during normal operation are characterized by random load alternation, which leads to the linear recording of fatigue damage summation.
V.L.

A93-18334
DESIGN CHARACTERISTICS OF THE FUNCTIONAL SYSTEMS OF AIRCRAFT AND PREDICTION OF THEIR TECHNICAL CONDITION [KONSTRUKTIVNYE OSOBENNOSTI FUNKTSIONAL'NYKH SISTEM VOZDUSHNYKH SUDOV I PROGNOZIROVANIE IKH TEKHNICHESKOGO SOSTOIANIIA]
F. K. GERMANCHUK (Kievskii Inst. Inzhenerov Grazhdanskoi Aviatsii, Kiev, Ukraine) and IA. D. SHEVCHENKO *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 36-39. In Russian. refs
Copyright

The paper is concerned with the problem of filter contamination in the hydraulic system of the TU-134 aircraft. A method for evaluating and predicting the technical condition of filter elements based on the contamination data is proposed which makes it possible to optimize the periodic maintenance schedule. A

nomogram for predicting the condition of a filter and scheduling its maintenance is presented. V.L.

A93-18339
CHARACTERISTICS OF FATIGUE CRACK GROWTH UNDER THE SERVICE-SPECTRUM LOADING OF THE TAIL BOOM OF A HELICOPTER [ZAKONOMERNOSTI ROSTA USTALOSTNYKH TRESHCHIN PRI EKSPLUATATSIONNOM SPEKTRE NAGRUZHENIIA KHVOSTOVOI BALKI VERTOLETA]
IU. M. PARAMONOV and M. L. SKRIPKA *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 63-69. In Russian. refs
Copyright
The parameters of fatigue crack growth in the tail boom of the MI-8 helicopter are investigated for a loading spectrum typical of operating conditions. Various methods of experimental data processing are discussed. Estimates of the parameters of fatigue crack growth models are obtained. V.L.

A93-18344
ANALYSIS OF RANDOM COMPONENTS DURING MEASUREMENTS IN THE COMPUTERIZED DIAGNOSTIC SYSTEM ANALIZ-86 [ISSLEDOVANIE SLUCHAINYKH SOSTAVLIAIUSHCHIKH PRI IZMERENIIAKH V AVTOMATIZIROVANNOI SISTEME DIAGNOSTIROVANIIA 'ANALIZ-86']
R. A. KOPYTOV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 88-93. In Russian. refs
Copyright
A method for isolating and analyzing the random components of measurement errors in a computerized diagnostic system for the IL-86 aircraft is described. By using the formalism of correlation functions and spectral analysis, it is shown that the random component constitutes white noise. The possibility of using the statistical averaging method for a selected flight data model in order to minimize the rms deviation is discussed. V.L.

A93-18349
A METHODOLOGICAL APPROACH TO THE DEVELOPMENT OF SERVICE AND TECHNICAL SPECIFICATIONS FOR AN ACTIVELY CONTROLLED MULTISTRUT LANDING GEAR [METODICHESKII PODKHOD K RAZRABOTKE EKSPLUATATSIONNO-TEKHNICHESKIKH TREBOVANII K AKTIVNO UPRAVLIAEMOMU MNOGOOPORNOMU SHASSI]
A. I. MATVEEV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 126-136. In Russian. refs
Copyright
An approach to the fomulation of principal requirements for the actuating mechanisms and automatic control systems of actively controlled multistrut landing gear is presented. Examples of implementations of multistrut landing gear requirements are examined. Some methodological aspects of the synthesis and optimization of active landing gear parameters are briefly discussed. V.L.

A93-18351
OPTIMIZING THE CRUISING FUEL EFFICIENCY OF COMMERCIAL AIRCRAFT ON THE BASIS OF FLIGHT MANUAL DATA [OPTIMIZATSIIA RASKHODA TOPLIVA NA KREISERSKOM REZHIME SAMOLETA GA PO DANNYM RLE]
M. PAVLIKA and V. A. SANNIKOV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 144-151. In Russian. refs
Copyright
A method is presented for selecting the Mach number of the cruising flight for maximum fuel efficiency. The approach proposed here allows for the wind direction and velocity. A nomogram is included which provides a convenient way of determining the flight Mach number for optimum fuel efficiency depending on the wind parameters, flight altitude, and aircraft weight. V.L.

A93-18354
EXPANDING THE OPERATION SCOPE OF AIRCRAFT THROUGH THE USE OF AIR-CUSHION LANDING GEAR [RASSHIRENIE EKSPLUATATSIONNYKH VOZMOZHNOSTEI SAMOLETOV NA OSNOVE PRIMENENIIA SHASSI NA VOZDUSHNOI PODUSHKE /SHVP/]
V. Z. SHESTAKOV and E. V. ZAREMBA *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 9-13. In Russian. refs
Copyright
The possibility of using the contact-type air-cushion landing gear is examined. In contrast to the classical air-cushion landing gear, this type of landing gear has an auxiliary wheel-type landing gear which comes in contact with the landing surface. The advantages of this approach are examined, and results of full-scale tests are reported. V.L.

A93-18361
CHARACTERISTICS OF THE DIAGNOSTICS OF BOOSTER SYSTEM COMPONENTS [OSOBENNOSTI DIAGNOSTIKI AGREGATOV BUSTERNYKH SISTEM]
A. V. MILTO, I. I. MININ, I. S. SHUMILOV, and Z. I. RUTKOVSKAIA *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 41-46. In Russian. refs
Copyright
An approach to the diagnostics of the booster system components of aircraft on the basis of the 'internal nonhermiticity' parameter is examined. Results of experimental studies conducted on real booster systems are reported. Based on an analysis the results of these studies, some characteristic features of the monitoring of the conditions of booster system components are identified. V.L.

A93-18367
MONITORING THE PURITY OF THE WORKING FLUIDS OF AIRCRAFT HYDRAULIC SYSTEMS DURING SERVICE [O KONTROLE CHISTOTY RABOCHIKH ZHIDKOSTEI GIDROSISTEM VOZDUSHNYKH SUDOV V PROTSESSE EKSPLUATATSII]
I. I. MININ, V. V. BUZENKOV, R. IU. ZHAROV, I. S. SHUMILOV, and Z. I. RUTKOVSKAIA *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 76-79. In Russian. refs
Copyright
A study is made of the composition of hydraulic fluid contaminants and of the dynamics of quantitative and qualitative changes in fluid composition. The effect of fluid contaminants on the performance of a hydraulic system is analyzed. Possible methods of monitoring the level of hydraulic fluid contamination are briefly discussed. V.L.

A93-18374
ANALYSIS OF THE PUMP STATION OF AN AIRCRAFT HYDRAULIC SYSTEM AS A SUBJECT OF DIAGNOSIS [ANALIZ NASOSNOI STANTSII SAMOLETNOI GIDROSISTEMY KAK OB'EKTA DIAGNOSTIROVANIIA]
S. V. GROKHOL'SKII and I. I. MININ *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 107-114. In Russian. refs
Copyright
A typical electrically powered pump station of an aircraft hydraulic system is examined from the standpoint of its diagnosability. A generalized functional model of the pump station is presented, and its possible technical states and service-related factors affecting it are identified. Based on an analysis of these data, methods are proposed for defining the structural parameters of the pump station and selecting those parameters that have the highest diagnostic value. V.L.

A93-18755
THE DESIGNS FOR SAFETY
G. SOUTHCOMBE (British Aerospace /Commercial Aircraft/, Ltd.,

Airbus Div., Bristol, United Kingdom) *In* Key trends in human factors of aircraft maintenance; Proceedings of the Conference, London, United Kingdom, Oct. 31, 1991 London Royal Aeronautical Society 1991 p. 2.1-2.7. refs
Copyright

The paper outlines the numerous activities during the design process where human factors have some bearing on maintenance. Apart from the operational requirements the processes which are dictated by the airworthiness requirements are numerous and very demanding. Considerations to be taken into account are: latent failures, checkability, zonal safety, maintenance errors, software design errors, M.S.G. Analysis, and ETOPS requirements. Author

A93-19185
LYNX: HIGH PERFORMANCE - LOW NOISE
JOHN W. LEVERTON (Westland, Inc., Arlington, VA) and TONY C. PIKE (Westland Helicopters, Ltd., Yeovil, United Kingdom) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 532-541. refs

A brief history of the Lynx helicopter, its initial design/requirements, acoustic characteristics, main rotor/tail rotor interaction, and quiet tail rotor program are discussed. Investigations conducted using the Lynx Mk1 confirmed the presence of two noise sources associated with the intersection by the tail rotor of the tip vortices shed by the main rotor. This research, which included theoretical modeling as well as experimental studies, led to the design and flight evaluation of a quiet tail rotor which demonstrated noise reductions of up to 15 dB on approach and 5 dB (A) at overhead. This successful concept was incorporated in the Lynx Mk7 and subsequent variants. To further enhance the performance of the Lynx family, the main rotor blades were recently replaced with BERP blades. This further aided noise control and as a result the latest versions of the high-performance/high-speed Lynx meets the most demanding civil certification standards. C.A.B.

A93-19231* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE PREDICTION OF NONLINEAR DYNAMIC LOADS ON HELICOPTERS FROM FLIGHT VARIABLES USING ARTIFICIAL NEURAL NETWORKS
A. B. COOK, C. R. FULLER, W. F. O'BRIEN, and R. H. CABELL (Virginia Polytechnic Inst. and State Univ., Blacksburg) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 971-979. Research supported by U.S. Army refs
(Contract NAG1-762)

A method of indirectly monitoring component loads through common flight variables is proposed which requires an accurate model of the underlying nonlinear relationships. An artificial neural network (ANN) model learns relationships through exposure to a database of flight variable records and corresponding load histories from an instrumented military helicopter undergoing standard maneuvers. The ANN model, utilizing eight standard flight variables as inputs, is trained to predict normalized time-varying mean and oscillatory loads on two critical components over a range of seven maneuvers. Both interpolative and extrapolative capabilities are demonstrated with agreement between predicted and measured loads on the order of 90 percent to 95 percent. This work justifies pursuing the ANN method of predicting loads from flight variables. Author

A93-19299
CIVIL AIRCRAFT CHALLENGES IN ENGINE/AIRFRAME INTEGRATION
GORDON L. HAMILTON and H. R. WELGE (Douglas Aircraft Co., Long Beach, CA) Jun. 1992 4 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-45)

Four areas of technology development are presently examined from a civil aircraft powerplant design-integration viewpoint: (1) subsonic ultrahigh-bypass turbofan propulsion integration; (2) supersonic inlets for SST powerplants; (3) integrated flight and propulsion controls; and (4) laminar flow controls. Attention is given to the 'flade', or fan-on-blade bypass duct variable-cycle/low-SFC engine for a high-speed civil transport. O.C.

A93-19552
AIRCRAFT ENGINE INTEGRATION FOR THE M88-RAFALE COUPLE
PHILIPPE RAMETTE (Dassault Aviation, Saint-Cloud, France) and JEAN C. CORDE (SNECMA, Paris, France) Jun. 1992 5 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992
(ASME PAPER 92-GT-403)

An aircraft/engine interface that was fully specified at the very outset of full scale development for the M88-2 engine and Rafale fighter airframe has allowed the two to be joined on-schedule. The primary areas of aircraft/engine integration affected by this initial specification encompassed electronic connections, air-intake aerodynamic characteristics, exhaust nozzle design, and installation suspension system. O.C.

A93-19806*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AERODYNAMIC OPTIMIZATION OF AN HSCT CONFIGURATION USING VARIABLE-COMPLEXITY MODELING
M. G. HUTCHISON, W. H. MASON, B. GROSSMAN, and R. T. HAFTKA (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jan. 1993 18 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG1-1160; NSF DDM-90-08451)
(AIAA PAPER 93-0101) Copyright

An approach to aerodynamic configuration optimization is presented for the high-speed civil transport (HSCT). A method to parameterize the wing shape, fuselage shape and nacelle placement is described. Variable-complexity design strategies are used to combine conceptual and preliminary-level design approaches, both to preserve interdisciplinary design influences and to reduce computational expense. Conceptual-design-level (approximate) methods are used to estimate aircraft weight, supersonic wave drag and drag due to lift, and landing angle of attack. The drag due to lift, wave drag and landing angle of attack are also evaluated using more detailed, preliminary-design-level techniques. New, approximate methods for estimating supersonic wave drag and drag due to lift are described. The methodology is applied to the minimization of the gross weight of an HSCT that flies at Mach 2.4 with a range of 5500 n.mi. Results are presented for wing planform shape optimization and for combined wing and fuselage optimization with nacelle placement. Case studies include both all-metal wings and advanced composite wings. Author

A93-20150#
WIND TUNNEL INVESTIGATION WITH AN OPERATIONAL TURBOJET ENGINE
LAMAR M. AUMAN (U.S. Army, Missile Command, Redstone Arsenal, AL) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0036)

Results are presented from a wind tunnel test (conducted in the Calspan's Transonic Wind Tunnel in Buffalo, New York) of a turbojet powered missile with the engine installed and operating at Mach numbers from 0.05 to 0.80. The purpose of this test was to investigate the stability and control, the performance of the installed engine at flight conditions, and plume interactions or aft heating problems. It was found that the worst case in terms of aft heating occurred at high engine throttle settings and low freestream (or static) velocities. I.S.

A93-20278# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DEVELOPMENT OF THE QUASI-PROCEDURAL METHOD FOR USE IN AIRCRAFT CONFIGURATION OPTIMIZATION

P. GAGE and I. KROO (Stanford Univ., CA) Sep. 1992 11 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 refs
(Contract NAG1-1052; NAG2-640)
(AIAA PAPER 92-4693) Copyright

The performance of the quasi-procedural analysis system in optimization tasks is investigated. In particular, the quasi-procedural method is applied to the complete mission optimization of a medium-sized transport aircraft using a vortex-lattice aerodynamic model and finite element structural analysis of the wing and the tail. Some modifications and improvements to the system, required in order to complete this task, are described. The performance of the system is compared with that of the standard procedural system, and it is shown that the quasi-procedural approach reduces the analysis required to reach the optimum. The overall cost is shown to be strongly dependent on the analysis architecture and data structure. V.L.

A93-20279*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
VARIABLE-COMPLEXITY AERODYNAMIC-STRUCTURAL DESIGN OF A HIGH-SPEED CIVIL TRANSPORT WING
M. G. HUTCHISON, X. HUANG, W. H. MASON, R. T. HAFTKA, and B. GROSSMAN (Virginia Polytechnic Inst. and State Univ., Blacksburg) Sep. 1992 19 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 refs
(Contract NAG1-1160; NSF DDM-90-08451)
(AIAA PAPER 92-4695) Copyright

A variable-complexity strategy of combining simple and detailed analysis methods is presented for the design optimization of a high-speed civil transport (HSCT) wing. Two sets of results are shown: the aerodynamic design of the wing using algebraic weight equations for structural considerations, and optimization results of the internal wing structure for a fixed wing configuration. We show example results indicating that using simple analysis methods alone for the calculation of a critical constraint can allow an optimizer to exploit weaknesses in the analysis. The structural optimization results provide a valuable check for the weight equations used in the aerodynamic design. In addition, these results confirm the need for using simple, algebraic models in conjunction with more detailed analysis methods. A strategy of interlaced aerodynanic-structural design is proposed. Author

A93-20281# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CONCURRENT OPTIMIZATION OF AIRFRAME AND ENGINE DESIGN PARAMETERS
THOMAS M. LAVELLE, ROBERT M. PLENCNER, and JONATHAN A. SEIDEL (NASA, Lewis Research Center, Cleveland, OH) Sep. 1992 16 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 Previously announced in STAR as N93-12402 refs
(Contract RTOP 505-69-50)
(AIAA PAPER 92-4713) Copyright

An integrated system for the multidisciplinary analysis and optimization of airframe and propulsion design parameters is being developed. This system is known as IPAS, the Integrated Propulsion/Airframe Analysis System. The traditional method of analysis is one in which the propulsion system analysis is loosely coupled to the overall mission performance analysis. This results in a time consuming iterative process. First, the engine is designed and analyzed. Then, the results from this analysis are used in a mission analysis to determine the overall aircraft performance. The results from the mission analysis are used as a guide as the engine redesigned and the entire process repeated. In IPAS, the propulsion system, airframe, and mission are closely coupled. The propulsion system analysis code is directly integrated into the mission analysis code. This allows the propulsion design parameters to be optimized along with the airframe and mission design parameters, significantly reducing the time required to obtain an optimized solution. Author

A93-20287#
AEROELASTIC OPTIMIZATION OF A COMPOSITE HELICOPTER ROTOR
RANJAN GANGULI and INDERJIT CHOPRA (Maryland Univ., College Park) Sep. 1992 22 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 refs
(Contract DAAL03-88-C-0002)
(AIAA PAPER 92-4780) Copyright

A design oriented analysis and an optimization methodology are developed by coupling a composite rotor dynamics analysis code and the design sensitivity analysis with a constrained optimization program. This approach is applied to an aeroelastic optimization problem involving the minimization of the 4/rev oscillatory hub loads of a four-bladed rotor subject to frequency and stability constraints. The optimum design solution for a box-beam configuration with no elastic couplings shows a reduction in the objective function of about 40 percent. The effect of elastic couplings is relatively small, with reductions in the objective function of less than 10 percent. The optimum design solution for a box-beam configuration with pitch-lag coupling shows an increase in lag damping of over 100 percent. V.L.

A93-20289#
MULTIDISCIPLINARY OPTIMIZATION OF HELICOPTER ROTOR BLADES INCLUDING DESIGN VARIABLE SENSITIVITY
THOMAS R. MCCARTHY and ADITI CHATTOPADHYAY (Arizona State Univ., Tempe) Sep. 1992 11 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 refs
(AIAA PAPER 92-4783) Copyright

The paper addresses a fully integrated optimization procedure, for helicopter rotor blades, with the coupling of blade dynamics, aerodynamics, aeroelasticity and structures. The goal is to reduce vibratory shear forces at the blade root with constraints imposed on critical dynamic, aerodynamic, aeroelastic and structural design requirements. The blade is modeled with a composite box beam as the principal load carrying member. Nonlinear chord and twist variations are assumed. A wide range of both structural and aerodynamic design variables are used along with several subsets to determine the sensitivity of the design variables on the optimum design. The optimization problem is formulated with two objective functions and the Kreisselmeier-Steinhauser function approach for multiple design objectives is used. A nonlinear programming technique and an approximate analysis procedure are used for optimization. The procedure yields substantial reductions in the vibratory root forces and moments along with significant improvements in the remaining design requirements. Results are presented for several different cases of design variable vectors and are compared with a baseline, or reference blade. Author

A93-20290#
INFLUENCE OF SWEEP ON STRUCTURAL OPTIMIZATION OF A FIGHTER WING
F. MEI and A. G. STRIZ (Oklahoma Univ., Norman) Sep. 1992 11 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 refs
(AIAA PAPER 92-4794) Copyright

The structural weight optimization with aeroelastic constraints (strength and flutter/divergence) of two fighter-type wing models with sweep angles from -36 to +36 deg, one made entirely of metal, the other with composite wing skins, is examined. Flutter and divergence analyses are performed to provide relevant constraint information for the optimization procedure. The flutter speeds are found to be higher for the swept backward composite wings when compared to the metal wings with the same sweep angle. Composite wing skin material is investigated to test its ability to prevent flutter and divergence as opposed to a metal

skin. Different design variable linking schemes are carried out to investigate their influence on the optimal design. It is shown that, for most of the cases, the weight of the metal wing is decreased by the optimization and can be decreased further by using composite wing skins. C.A.B.

A93-20295*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

AERODYNAMIC PERFORMANCE OPTIMIZATION OF A ROTOR BLADE USING A NEURAL NETWORK AS THE ANALYSIS

WILLIAM J. LAMARSH, II (Unisys Corp., Hampton, VA), JOANNE L. WALSH, and JAMES L. ROGERS (NASA, Langley Research Center, Hampton, VA) Sep. 1992 16 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 refs

(AIAA PAPER 92-4837) Copyright

This paper describes the use of neural networks as a replacement for rotor analyses in a conventional aerodynamic performance optimization procedure. The optimization procedure minimizes an objective function, a linear combination of horsepower required for hover, forward flight, and maneuver. The design variables are pretwist, taper initiation, taper ratio, and blade root chord. Constraints consist of limits on horsepower required (for hover, forward flight, and maneuver), stall, trim, and minimum tip chord. Neural network analyses agree with conventional analyses. Author

A93-20296*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

MULTIDISCIPLINARY DESIGN INTEGRATION SYSTEM FOR A SUPERSONIC TRANSPORT AIRCRAFT

A. R. DOVI, G. A. WRENN (Lockheed Engineering and Sciences Co., Hampton, VA), J.-F. M. BARTHELEMY, P. G. COEN (NASA, Langley Research Center, Hampton, VA), and L. E. HALL (Unisys Corp., Hampton, VA) Sep. 1992 13 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 refs

(AIAA PAPER 92-4841) Copyright

An aircraft preliminary design system which provides the multidisciplinary communications and couplings between several engineering disciplines is described. A primary benefit of this system is to demonstrate advanced technology multidisciplinary design integration methodologies. The current version includes the disciplines of aerodynamics and structures. Contributing engineering disciplines are coupled using the Global Sensitivity Equation approach to influence the global design optimization problem. A high speed civil transport configuration is used for configuration trade studies. Forty four independent design variables are used to control the cross-sectional areas of wing rib and spar caps and the thicknesses of wingskincover panels. A total of 300 stress, strain, buckling and displacement behavioral constraints and minimum gages on the design variables were used to optimize the idealized wing structure. The goal of the designs to resize the wing cover panels and internal structure for minimum mass. Author

A93-20307*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

INTEGRATED AERODYNAMIC-STRUCTURAL-CONTROL WING DESIGN

M. RAIS-ROHANI (Mississippi State Univ., Mississippi), R. T. HAFTKA, B. GROSSMAN, and E. R. UNGER (Virginia Polytechnic Inst. and State Univ., Blacksburg) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 52-62. refs

(Contract NSF DMC-86-15336; NAG1-224)

(AIAA PAPER 92-4694) Copyright

The aerodynamic-structural-control design of a forward-swept composite wing for a high subsonic transport aircraft is considered. The structural analysis is based on a finite-element method. The aerodynamic calculations are based on a vortex-lattice method, and the control calculations are based on an output feedback control. The wing is designed for minimum weight subject to structural, performance/aerodynamic and control constraints. Efficient methods are used to calculate the control-deflection and control-effectiveness sensitivities which appear as second-order derivatives in the control constraint equations. To suppress the aeroelastic divergence of the forward-swept wing, and to reduce the gross weight of the design aircraft, two separate cases are studied: (1) combined application of aeroelastic tailoring and active controls; and (2) aeroelastic tailoring alone. The results of this study indicated that, for this particular example, aeroelastic tailoring is sufficient for suppressing the aeroelastic divergence, and the use of active controls was not necessary. Author

A93-20308*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

MULTIDISCIPLINARY ANALYSIS AND SENSITIVITY DERIVATIVES FOR ISOLATED HELICOPTER ROTORS IN HOVER

HENRY E. JONES (U.S. Army, Aeroflightdynamics Directorate; NASA, Langley Research Center, Hampton, VA), GENE W. HOU, PRANAV D. PATWA, SATISH V. MANI (Old Dominion Univ., Norfolk, VA), PERRY A. NEWMAN (NASA, Langley Research Center, Hampton, VA), ARTHUR C. TAYLOR, III, and MOHAN KORIVI (Old Dominion Univ., Norfolk, VA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 63-86. refs

(AIAA PAPER 92-4696) Copyright

A new method is presented for using Navier-Stokes results in the system analysis and sensitivity derivative computations for a helicopter rotor in hover. The system coupling includes the interactions between rotor performance, rotor structural properties and aerodynamics (i.e., airfoil shape). Emphasis is placed on the use of high fidelity Navier-Stokes algorithms for the aerodynamic problem. The present formulation is chosen to reduce the number of sensitivity derivative equations and their dimensions as much as possible. In addition, an alternative adjoint formulation is presented which dramatically reduces the computational requirement for disciplines in which there may be a large number of design variables (e.g., aerodynamics). The theoretical method makes use of a combination of derivatives from each discipline; the computation of these derivatives has already been shown to be feasible. Sample computations for the aerodynamic-rotor model coupling and an associated sensitivity derivative are also presented. Author

A93-20322*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

AEROSERVOELASTICITY IN HISAIR

THOMAS A. ZEILER (Lockheed Engineering & Sciences Co., Hampton, VA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 234-243. refs

(Contract NAS1-19000)

(AIAA PAPER 92-4719)

The High Speed Airframe Integration Research project is a multidisciplinary effort to bridge disciplinary boundaries in the analysis and design of aircraft. Aeroservoelasticity provides calculations of various critical speeds (such as flutter, divergence, and control reversal), of hump mode dampings, and of the effects of flexibility on vehicle stability and control derivatives. For design iterations, sensitivity derivatives of these characteristics with respect to structural design variables are also calculated. For executing this function, a set of computer programs was developed or adapted to perform routine calculations of basic aeroelastic characteristics. This set of programs, named the Aeroelastic Vehicle Analysis system, has also become a useful tool within the Aeroservoelasticity Branch of NASA's Langley Research Center. Author

A93-20323#

PRELIMINARY WING DESIGN OF A HIGH SPEED CIVIL TRANSPORT AIRCRAFT BY MULTILEVEL DECOMPOSITION TECHNIQUES

PETER J. ROHL and DANIEL P. SCHRAGE (Georgia Inst. of Technology, Atlanta) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 244-250. refs

(AIAA PAPER 92-4721) Copyright

A multilevel decomposition approach for the preliminary design of a High Speed Civil Transport (HSCT) aircraft wing structure is described. The wing design is decomposed into three levels. The top level uses the ACSYNT aircraft synthesis program to generate preliminary weight, mission and performance information needed for the calculations. The optimization criterion is productivity as expressed by a productivity index for a specified mission. The second level of the system performs a basic finite element structural analysis of the wing box. The wing structure is sized for minimum weight subject to structural and aeroelastic constraints. Sensitivity derivatives are computed with respect to the top level design variables. Level 3 performs a detailed stress and buckling analysis of the wing skin panels and thus creates an updated wing weight that is passed to the top level together with the sensitivity information. The methodology will be verified using a baseline HSCT configuration derived from the NASA HiSAIR studies. Currently data acquisition and computer program installation are in progress. Author

A93-20324*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

STRUCTURAL TAILORING/ANALYSIS FOR HYPERSONIC COMPONENTS - A COMPUTATIONAL SIMULATION

G. V. NARAYANAN, E. S. REDDY, G. ABUMERI (Sverdrup Technology, Inc., Brook Park, OH), DALE A. HOPKINS, and CHRISTOS C. CHAMIS (NASA, Lewis Research Center, Cleveland, OH) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 251-262. refs

(Contract NAS3-25266)

(AIAA PAPER 92-4722) Copyright

The development of STAHYC (Structural Tailoring/Analysis for Hypersonic Components), a numerical tool for the optimum design of an engine inlet wall panel for hypersonic aerospace vehicles, is described. STAHYC integrates FORTRAN modules of different disciplines, including fluid dynamics, heat transfer, structural analysis, and optimization. The discussion covers the system design concept, system components, system automation, system testing, established links, and data transfer between different computational modules. The various algorithms used in STAHYC are also discussed. V.L.

A93-20328*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

SURVEY - APPLICATIONS OF STRUCTURAL OPTIMIZATION METHODS TO FIXED WING AIRCRAFT AND SPACECRAFT

HIROKAZU MIURA (NASA, Ames Research Center, Moffett Field, CA) and DOUGLAS J. NEILL (Universal Analytics, Inc., Torrance, CA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 298-322. refs

(AIAA PAPER 92-4726) Copyright

Results of a technical survey of the practical applications of structural optimization methods in the U.S. aerospace industry through 1980s are summarized. One of the most important developments in the 80s is the more widespread acceptance of structural optimization as one of the design tools that support practical structural design. Another significant advance is the development of large software tools for production applications. Attention is also given to the tailoring of the computerized design process to the specific environment of each company. The two most important aspects of this tailoring are seamless and easy-to-use incorporation of structural optimization in the overall aerospace design/production process and multidisciplinary integration aimed at ultimate performance optimization of the final product. Some specific applications discussed include the X-29 forward swept wing demonstrator aircraft, composite wing and vertical tail program, fighter wing redesign evaluations, high speed aircraft design, and space structures. V.L.

A93-20356*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

STRUCTURAL OPTIMIZATION FOR JOINED-WING SYNTHESIS

JOHN W. GALLMAN (NASA, Ames Research Center, Moffett Field, CA) and ILAN M. KROO (Stanford Univ., CA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 582-594. refs

(AIAA PAPER 92-4761) Copyright

The differences between fully stressed and minimum-weight joined-wing structures are identified, and these differences are quantified in terms of weight, stress, and direct operating cost. A numerical optimization method and a fully stressed design method are used to design joined-wing structures. Both methods determine the sizes of 204 structural members, satisfying 1020 stress constraints and five buckling constraints. Monotonic splines are shown to be a very effective way of linking spanwise distributions of material to a few design variables. Both linear and nonlinear analyses are employed to formulate the buckling constraints. With a constraint on buckling, the fully stressed design is shown to be very similar to the minimum-weight structure. It is suggested that a fully stressed design method based on nonlinear analysis is adequate for an aircraft optimization study. P.D.

A93-20360#

STATIC AEROELASTIC ANALYSIS OF A MANEUVERING AIRCRAFT WITH DAMAGED WING

JONG-HO WOO (U.S. Army, Ballistic Research Lab., Aberdeen Proving Ground, MD) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 626-637. refs

(AIAA PAPER 92-4765)

This paper describes an analysis of the static aeroelastic response of an aircraft with asymmetrical wing planforms representing combat damage using the MSC/NASTRAN Aeroelastic Code. Wings (with ailerons), stabilators, and vertical wings (with rudders) are considered as lifting and control surfaces in the aerodynamic model. Structural and aerodynamic analyses are based on the finite element approach and are created independently for both the damaged and undamaged cases. Five different wing structural models, one undamaged and four damaged, are examined in this paper. Doublet-Lattice subsonic theory is used to account for interference effects among multiple lifting surfaces and bodies. The stability and control derivatives, airloads, and trim values are obtained for the damaged-wing aircraft. Effects of the static aeroelastic analysis of the damaged wing on the aircraft's maneuvering flight are discussed. Author

A93-20369# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

RECENT ADVANCES IN INTEGRATED MULTIDISCIPLINARY OPTIMIZATION OF ROTORCRAFT

HOWARD M. ADELMAN, JOANNE L. WALSH, and JOCELYN I. PRITCHARD (NASA, Langley Research Center, Hampton, VA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 710-721. Previously announced in STAR as N93-10968 refs

(Contract RTOP 505-63-36-06)
(AIAA PAPER 92-4777) Copyright

A joint activity involving NASA and Army researchers at NASA LaRC to develop optimization procedures to improve the rotor blade design process by integrating appropriate disciplines and accounting for all of the important interactions among the disciplines is described. The disciplines involved include rotor aerodynamics, rotor dynamics, rotor structures, airframe dynamics, and acoustics. The work is focused on combining these five key disciplines in an optimization procedure capable of designing a rotor system to satisfy multidisciplinary design requirements. Fundamental to the plan is a three-phased approach. In phase 1, the disciplines of blade dynamics, blade aerodynamics, and blade structure are closely coupled while acoustics and airframe dynamics are decoupled and are accounted for as effective constraints on the design for the first three disciplines. In phase 2, acoustics is integrated with the first three disciplines. Finally, in phase 3, airframe dynamics is integrated with the other four disciplines. Representative results from work performed to date are described. These include optimal placement of tuning masses for reduction of blade vibratory shear forces, integrated aerodynamic/dynamic optimization, and integrated aerodynamic/dynamic/structural optimization. Examples of validating procedures are described. Author

A93-20370* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

DEVELOPMENT OF A STRUCTURAL OPTIMIZATION CAPABILITY FOR THE AEROELASTIC TAILORING OF COMPOSITE ROTOR BLADES WITH STRAIGHT AND SWEPT TIPS

P. P. FRIEDMANN, C. VENKATESAN, and K. YUAN (California Univ., Los Angeles) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 722-748. refs
(Contract NAG1-833)
(AIAA PAPER 92-4779) Copyright

This paper describes the development of a new structural optimization capability aimed at the aeroelastic tailoring of composite rotor blades with straight and swept tips. The primary objective is to reduce vibration levels in forward flight without diminishing the aeroelastic stability margins of the blade. In the course of this research activity a number of complicated tasks have been addressed: (1) development of a new, aeroelastic stability and response analysis; (2) formulation of a new comprehensive sensitive analysis, which facilitates the generation of the appropriate approximations for the objective and the constraints; (3) physical understanding of the new model and, in particular, determination of its potential for aeroelastic tailoring, and (4) combination of the newly developed analysis capability, the sensitivity derivatives and the optimizer into a comprehensive optimization capability. The first three tasks have been completed and the fourth task is in progress. Author

A93-20371#

AN APPROACH TO TILTROTOR WING AEROSERVOELASTIC OPTIMIZATION THROUGH INCREASED PRODUCTIVITY

MARTIN STETTNER and DANIEL P. SCHRAGE (Georgia Inst. of Technology, Atlanta) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 749-759. Research supported by Sikorsky Aircraft refs
(AIAA PAPER 92-4781) Copyright

The paper describes one way to approach the multidisciplinary task of optimizing a tiltrotor wing structure which is equipped with an active flutter suppression system. Objective function is a productivity index, as a measure for aircraft cost-effectiveness. Short digress is held on the characteristics of the tiltrotor's dynamic system and its aeroelastic behavior. Contributing analyses (CA's) for calculating aircraft performance, modeling the dynamic system, and designing an active flutter suppression control system are selected. Multilevel and non-hierarchic decomposition techniques are discussed. A file structure for handling data transfer between the CA's and the optimizer is presented. Preliminary results are shown which highlight some peculiarities of this optimization problem. Author

A93-20372

VIBRATION REDUCTION FOR HELICOPTER AIRFRAMES - AN APPLICATION OF THE GENERAL-PURPOSE STRUCTURAL OPTIMIZATION PROGRAM STARS

P. BARTHOLOMEW (Defence Research Agency, Materials and Structures Dept., Farnborough, United Kingdom) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 760-766. refs
(AIAA PAPER 92-4782) Copyright

A progress report on a program to address the use of both active and passive helicopter design freedoms is presented. The main application is based on the use of a model of the Westland LYNX helicopter, the objective being to employ structural optimization techniques to enhance passive vibration reduction. It was found necessary to treat static strength requirements simultaneously with vibration considerations, and the imposition of constraints on natural frequency is found to yield substantial benefits in terms of stability of the optimization algorithm. Methods for including active vibration-control systems in the model are considered. Iteration history showing natural frequencies and amplitude of vibration is illustrated. P.D.

A93-20381#

FLUTTER OPTIMIZATION OF LARGE TRANSPORT AIRCRAFT

GREGORY D. SIKES, GEORGE T. J. TZONG, and ANIL K. SHARMA (Douglas Aircraft Co., Long Beach, CA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 853-862. refs
(AIAA PAPER 92-4795) Copyright

This paper presents flutter optimization of three different aircraft models using the Aeroelastic Design Optimization Program. These studies focus on the design of structural parameters, such as beam bending stiffness, skin thickness, stringer area, lumped mass value and offset, engine location and pylon stiffness to satisfy the flutter requirements while minimizing weight. Some basic finite element technology, related to optimization, is summarized. Flutter optimization topics including case control logic, flutter analysis, design sensitivities, modal analysis, and design of general stiffness/flexibility elements are also discussed. Author

A93-21125* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

DYNAMIC ANALYSIS OF PRETWISTED ELASTICALLY-COUPLED ROTOR BLADES

MARK W. NIXON and HOWARD E. HINNANT (U.S. Army, Aerostructures Directorate; NASA, Langley Research Center, Hampton, VA) Nov. 1992 17 p. ASME, Winter Annual Meeting, Anaheim, CA, Nov. 8-13, 1992, Paper refs

This paper addresses the accuracy of using a one-dimensional analysis to predict frequencies of elastically-coupled highly-twisted rotor blades. Degrees of freedom associated with shear deformation are statically condensed from the formulation, so the analysis uses only those degrees of freedom associated with classical beam theory. The effects of cross section deformation (warping) are considered, and are shown to become significant for some types of elastic coupling. Improved results are demonstrated for highly-coupled blade structures through account of warping in a local cross section analysis, without explicit inclusion of these effects in the beam analysis. A convergence study is also provided which investigates the potential for improving efficiency of elastically-coupled beam analysis through implementation of a p-version beam finite element. Author

A93-21836
ADVANCING HELICOPTERS
DOUGLAS BARRIE, KIERAN DALY, SIMON ELLIOTT, DAVID LEARMOUNT, GUY NORRIS, and PAUL PHELAN Flight International (ISSN 0015-3710) vol. 142, no. 4347 Dec. 2, 1992 p. 31, 32, 36, 37.
Copyright
This paper aims to show that advancing helicopter technology is not aimed at changing the shape of rotorcraft but to eliminate or overcome their inherent disadvantages. One novel technical project is designed to analyze airframe vibration caused by the rotor, process the information through an adaptive control unit and utilize actuators to introduce a counter vibration into the airframe. R.E.P.

A93-21843
THE BOEING 747-400 UPPER RUDDER CONTROL SYSTEM WITH TRIPLE TANDEM VALVE
HENRIK H. STRAUB (Boeing Commercial Airplane Group, Seattle, WA) and ROLAND CRESWELL (Parker Bertea Aerospace, Irvine, CA) *In* Advanced aerospace hydraulic systems and components Warrendale, PA Society of Automotive Engineers, Inc. 1991 p. 31-40.
(SAE PAPER 912133) Copyright
To the casual airline passenger the appearance of the Boeing 747-400 jetliner is identical to that of the older model 747-300 with the exception of the winglets. However, modifications and improvements include modern digital avionics, a 'glass' cockpit and more powerful rudder control surfaces to cope with the growth in engine thrust. The upper rudder is positioned by three parallel actuators and powered by two independent hydraulic systems. Flow control is provided by a triple tandem servovalve which maintains actuator force fight below allowable limits and synchronizes hydraulic flow to the three actuators. This paper describes the requirements, design, development, analysis and iron bird testing of some of the unique features of the upper rudder hydraulic control system. Author

A93-22002
A WIDEBAND, EMBEDDED/CONFORMAL, ANTENNA SUBSYSTEM CONCEPT
JOSEPH P. SMALANSKAS, GARY W. VALENTINE, and RONALD I. WOLFSON (Hughes Aircraft Co., Radar Systems Group, El Segundo, CA) *In* Structures sensing and control; Proceedings of the Meeting, Orlando, FL, Apr. 2, 3, 1991 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 2-8.
Copyright
The concept for a wideband, embedded/conformal antenna subsystem is presented. A multilayer radome not only protects the antenna from hostile environments, but is also designed to sustain aircraft dynamic loading. The radiating element consists of a planar, dual-flared slot capable of high-performance, multioctave operation. Advanced materials are currently being developed to enhance the low profile and efficient, wideband performance of the radiating element. Author

A93-22551*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
RESULTS OF LOW POWER DEICER TESTS ON A SWEPT INLET COMPONENT IN THE NASA LEWIS ICING RESEARCH TUNNEL
THOMAS H. BOND and JAIWON SHIN (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 20 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-14911 refs
(AIAA PAPER 93-0032) Copyright
Tests were conducted under a USAF/NASA Low Power Deicer program on two expulsive technologies to examine system performance on hardware representative of a modern aircraft part. The BF Goodrich Electro-Expulsive Deicing System and Pneumatic Impulse Ice Protection system were installed on a swept, compound curve, engine inlet component with varying leading edge radius, and tested through a range of icing and system operating conditions in the NASA Lewis Icing Research Tunnel. A description of the experimental procedure and results, including residual ice thickness, shed ice particle size, and changes in system energy/pressure characteristics are presented. Author

A93-22696*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MODELING AND STRAIN GAUGING OF EDDY CURRENT REPULSION DEICING SYSTEMS
SAMUEL O. SMITH (Electroimpact, Inc., Seattle, WA) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS3-26252)
(AIAA PAPER 93-0296) Copyright
Work described in this paper confirms and extends work done by Zumwalt, et al., on a variety of in-flight deicing systems that use eddy current repulsion for repelling ice. Two such systems are known as electro-impulse deicing (EIDI) and the eddy current repulsion deicing strip (EDS). Mathematical models for these systems are discussed for their capabilities and limitations. The author duplicates a particular model of the EDS. Theoretical voltage, current, and force results are compared directly to experimental results. Dynamic strain measurements results are presented for the EDS system. Dynamic strain measurements near EDS or EIDI coils are complicated by the high magnetic fields in the vicinity of the coils. High magnetic fields induce false voltage signals out of the gages. Author

A93-23072#
INVESTIGATION OF AN ELECTROTHERMAL DE-ICER PAD USING A THREE-DIMENSIONAL FINITE ELEMENT SIMULATION
J. R. HUANG, THEO G. KEITH, JR., and KENNETH J. DE WITT (Toledo Univ., OH) Jan. 1993 19 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0397) Copyright
A finite-element method, which incorporates an assumed phase state technique, is presented for the solution of one-, two- and three-dimensional heat conduction problems with phase change. A simulation of an electrothermal de-iced aircraft surface is made using this method. The major interest of this study is to fully investigate and understand various effects of a de-icer pad in chordwise and spanwise directions on the numerical results. Comparison of predicted temperatures reveals the extent and importance of modeling curvature in the chordwise direction, and wing sweep effects in the spanwise direction. To demonstrate the versatility of the method, a numerical simulation of a wing/fuselage intersection is considered. Author

A93-23242# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NUMERICAL MODELING OF ANTI-ICING SYSTEMS AND COMPARISON TO TEST RESULTS ON A NACA 0012 AIRFOIL
KAMEL M. AL-KHALIL and MARK G. POTAPCZUK (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15345 Research supported by National Research Council refs
(Contract RTOP 505-68-10)
(AIAA PAPER 93-0170) Copyright
A series of experimental tests were conducted in the NASA Lewis IRT on an electro-thermally heated NACA 0012 airfoil. Quantitative comparisons between the experimental results and those predicted by a computer simulation code were made to assess the validity of a recently developed anti-icing model. An infrared camera was utilized to scan the instantaneous temperature contours of the skin surface. Despite some experimental difficulties, good agreement between the numerical predictions and the experimental results were generally obtained for the surface temperature and the possibility for the runback to freeze. Some recommendations were given for an efficient operation of a thermal anti-icing system. Author

A93-23257#
EXPERIENCES IN FABRICATION OF A WAVERIDER MODEL FOR WIND TUNNEL TESTING
CURTIS BERRY, MARK KAMMEYER, EDWARD LARACH (U.S. Navy, Naval Surface Warfare Center, Silver Spring, MD), and DAVID BURNETT (McDonnell Douglas Corp., Huntington Beach, CA) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research sponsored by McDonnell Douglas Space Systems Co., U.S. Navy, and USAF refs
(AIAA PAPER 93-0510)
A wind tunnel test program is being planned to obtain static stability and drag, surface pressure, and heat transfer measurements on a hypersonic waverider. The objective is to validate a methodology for designing viscous-optimized waveriders which incorporate realistic leading edge radii. The point design for this test is Mach 14, ReL = 6.5 million. The tests will be conducted in the Naval Surface Warfare Center Hypervelocity Tunnel 9. This paper focuses on the task of fabricating the model, which has comprised the work performed to date. Specific issues addressed include compatibility of several CAD systems and data exchange formats among three organizations involved in the test. Author

N93-15858# Rutgers - The State Univ., Newark, NJ. Dept. of Physics.
F-14 WING LUG COATING INVESTIGATION Final Report, Sep. 1991 - Mar. 1992
DONALD J. HIRST and CHARLES R. HEGEDUS 15 Feb. 1992 26 p Sponsored by Naval Air Systems Command
(AD-A257384; NAWCADWAR-92045-60) Avail: CASI HC A03/MF A01
F-14 wing lugs have been painted with a special coating which prevents wear of the bearing and lug, and subsequent failure of the wing. The coating originally designated for this application contained talcs (extender pigments) which contain small concentrations of asbestos, causing discontinued manufacturing of the talcs and the coating. Since the performance of this coating is considered critical to flight, a replacement was needed to prevent grounding of the F-14 fleet. One requirement for the application of this coating was that it be processed by allowing the filler particles to settle, and subsequently decanting and applying the resin-rich upper layer of the mixed coating. The original coating was reformulated by replacing the talcs with non-asbestos pigments with nearly equivalent chemical composition. This resulted in a pigment systems which does not settle an much as that in the original coating, and the applied film is far less wear resistant. Alternative high performance coatings also displayed relatively poor abrasion resistance compared to the original coating. A mechanism for these results has been proposed. It is suspected that pigment-rich coatings with particles protruding through the surface allow the concentration of shear stresses. GRA

N93-16186# Systems Technology, Inc., Hawthorne, CA.
GROUND BASED SIMULATION EVALUATION OF THE EFFECTS OF TIME DELAYS AND MOTION ON ROTORCRAFT HANDLING QUALITIES Final Report, 16 Jul. - 17 Aug. 1990
DAVID G. MITCHELL, ROGER H. HOH, ADOLPH ATENCIO, JR., and DAVID L. KEY Jan. 1992 247 p Sponsored by Army Aviation Systems Command
(AD-A256921; REPT-1281-10-1; AVSCOM-TR-91-A-010) Avail: CASI HC A11/MF A03
An exploratory simulation was conducted on the NASA Ames Research Center's Vertical Motion Simulator (VMS) to evaluate the effects of simulator characteristics on handling qualities for performing hover and low-speed tasks in a helicopter. The primary focus of the study was on subjective assessments of the variations, based on Cooper-Harper Handling Qualities Ratings (HQR's), rather than objective measures of pilot performance. Effects of variations in the three major elements of the simulation (motion system, visual system, and math model) were evaluated. Seven precision and aggressive low speed Mission-Task-Elements were performed. All tasks were Level 2 (average HQR worse than 3.5) fixed-base for the baseline helicopter, which was designed to provide Level 1 handling qualities in the real world. Addition of motion improved ratings 1/2 to 2 points, resulting in Level 1 handling qualities for most tasks. Tradeoffs in motion acceleration gain and washout break frequency were evaluated with two sets of motion washouts. There was a preference for reduced washout frequencies (resulting in improved phasing between the visual and motion responses at mid helicopter, handling qualities, simulation, time delay, motion system to high frequencies, at the sacrifice of onset gain) for the precision tasks. Conversely, there was a slight preference for increased onset gains (at the sacrifice of visual/motion phasing) for the aggressive tasks. The effects on handling qualities of a visual delay compensation algorithm were investigated by three pilots. GRA

N93-16215# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.
STRESS CALCULATIONS ON THE WINDOW SECTION OF AN ALL-COMPOSITE AIRCRAFT FUSELAGE
M. J. L. VANTOOREN, G. A. M. SCHOLTEALBERS, and T. DEJONG Jul. 1992 103 p
(LR-688; ETN-92-92880) Avail: CASI HC A06/MF A02
An approximate solution for the stresses in an infinite orthotropic plate with a row of holes is presented. The calculations are based on the analytical method of complex stress functions. The complex stress functions are evaluated from the boundary conditions of the holes. The influence of each hole is represented by a Taylor expansion of the elementary stress functions belonging to that hole. The use of series implies a limited accuracy of the solution. The numerical evaluation however shows that the convergence of the series is good. In the stress calculations, arbitrary loading conditions can be applied at infinity and the row of holes can be orientated under an arbitrary angle with the symmetry axes of the material. Here two angles and a loading condition of plane stress were chosen. Numerical results are obtained for five carbon fiber reinforced laminates with three different pitch to hole diameter ratios. The isotropic case was added for reference purposes. A preliminary design of an all composite sandwich fuselage (150 seats) is also investigated. With the analytical method developed before, the required facing thickness for the window section is calculated using a modified Tsai-Hill criterion. The calculations reveal that so far, the window section is most efficiently reinforced with a 1.9 mm Carbon Fiber Reinforced Plastic (CFRP) laminate consisting for 60 percent of (+/- 45 deg) CFRP and for 40 percent of (0 to 90 deg) CFRP. ESA

N93-16262# San Diego State Univ., CA.
COCKPIT RESOURCE MANAGEMENT PROFICIENCY AS A FACTOR OF PRIMARY FLIGHT TRAINING M.S. Thesis
MATTHEW J. FALETTI Jul. 1992 56 p
(Contract N00123-89-G-0591)
(AD-A256995) Avail: CASI HC A04/MF A01
Since the first dual piloted aircraft flew in 1911, aircrew have been attempting to communicate with one another in the cockpit. As aircraft have become more sophisticated, the demands placed on crew members have increased dramatically. Aircrews have become more than manipulators of the controls, they now must consider all factors which may effect a flight from A to B. Often these factors will occur even before the aircraft leaves the ground. However, as the sophistication of aircraft has increased, little attention has been devoted toward the human factor in aviation. Statistics show that flight crews are responsible for approx. 80 pct. of the accidents that occur. The boom in technology and the resulting changing role of flight crew as managers and decision makers rather than continuous manipulators of the controls' have brought about a new term in aviation, Cockpit Resource Management (CRM). CRM attempts to explain and address the need and importance of the communication process in the cockpit, and an analysis of the flight crew as a system, rather than as isolated individuals. With such a large percentage of aircraft accidents resulting from crew error, it is important to ask if CRM skills can be effectively taught to pilots. The effectiveness is

addressed of the flight training programs within the Naval Air Training Command at instilling CRM skills to newly designated flight personnel. GRA

N93-16283# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.
THE AIRBUS FLOOR BEAM: TOWARDS A COST-EFFECTIVE COMPOSITE DESIGN AND MANUFACTURE RESEARCH PROJECT SPONSORED BY AIRBUS INDUSTRY
R. E. DEKOK Jan. 1992 62 p
(LR-677; ETN-92-92872) Avail: CASI HC A04/MF A01

The feasibility of the use of Continuous Fiber Reinforced Thermo Plastic (CFRTP) materials in primary load bearing aircraft structures is considered. The possibility of replacing aluminum floor beams with cost effective composite floor beams was investigated. Both the design and the manufacturing technology for a composite floor beam were studied. A typical 'square u' shaped floor beam of the A310 (part identification code 56) was selected initially to be replaced with a composite version which should act as a demonstrator. The restrictions that had to be met with are detailed. The aluminum floor beam is made from one single piece by numerically controlled milling machine. This process facilitates the production of a changing geometry to optimize the strength and stiffness of each beam individually. This method has resulted in a rather complex design for each single floor beam and a very large scrap percentage (approximately 75 percent). The project status is outlined. The design (requirements, calculations, ease of production), the selection of an adequate manufacturing technique and research results on the validation of these processes, are dealt with. It is shown that the specific nature of these materials, their inherent higher unit cost and their processing characteristics necessitate a change in the current design. This will enable the applications of relatively straightforward manufacturing processes and a standard laminate layup in order to arrive at a cost effectice part. ESA

N93-16287# Alenia Spazio S.p.A., Naples (Italy). Gruppo Aerei Trasporto.
REVIEW OF AERONAUTICAL FATIGUE INVESTIGATION ACTIVITIES DEVELOPED IN ALENIA-GAT DURING THE PERIOD MAY 1990 - MARCH 1991
A. MINUTO Mar. 1991 10 p Presented at the 5th AIFA Meeting, Parma, Italy, 17-19 Mar. 1991
(ETN-92-92884) Avail: CASI HC A02/MF A01

The main activities carried out by Alenia (Aeritalia and Selenia) GAT (Italian acronym for Air Transport Group) in the field of aeronautical fatigue are summarized. The ATR 42 and 72 full scale fatigue tests are described. These included: aircraft fatigue tests, horizontal tail fatigue tests, main landing gear fatigue tests and main landing gear support structure fatigue tests. The ATR 72 test also investigated rear entry door plug, carbon epoxy vertical tail and skin panels with bonded stringers. The MO 11 full scale a winglet assembly fatigue tests and the specimen fatigue tests are also described. The latter included crack propagation tests and analytical models comparison, fatigue characterization of carbon/epoxy solid laminates, fatigue characterization of aluminun alloys, and damage tolerance charaterization of aluminum lithium alloys. The test setups are illustrated. ESA

N93-16345# Technische Univ., Delft (Netherlands). Faculty of Aerospace Engineering.
HELICOPTER INSTALLATIONS: FROM MOTOR TO ROTOR [HELIKOPTER INSTALLATIES: VAN MOTOR TOT ROTOR]
J. F. BOER Dec. 1991 192 p In DUTCH
(LR-675; ETN-93-92870) Avail: CASI HC A09/MF A02

The primary installations of helicopters are described with a view to helicopter design. Some relevant helicopter principles are explained. The different types of engine installations, their fuel control systems, and instrumentation as well as the fuel installation are described. The general requirements for transmission systems, the different transmission configurations and their components, the lubrication of the gear casings, and the suspension of the main deceleration box are treated. Rotor heads, rotor blades, and couple compensation systems are presented. The different helicopter control systems are described. ESA

N93-16396# Orincon Corp., La Jolla, CA.
CONDITIONED BASED MACHINERY MAINTENANCE (HELICOPTER FAULT DETECTION) Progress Report, 1 Jul. - 31 Aug. 1992
27 Aug. 1992 9 p
(Contract N00014-92-C-0059)
(AD-A255796; OC-R-92-U-0349) Avail: CASI HC A02/MF A01

A problem of current interest is the automatic detection and classification of faults in mechanical systems such as the gearboxes and transmissions on board helicopters. Current fault processing uses relatively simple metrics to characterize changes in measured vibration data. The metric specification and thresholds for detection and classification are found using complicated analytic models for the gearboxes. With this approach, finding a solution to the problem is difficult since the understanding of the problem, the metrics that can be used, and the fault classes that are accounted for are only as good as the model developed. In many cases, the interaction of fault conditions with the mechanical system is time varying and highly nonlinear. An alternative solution described here is to use generalized time-frequency and time-scale representations coupled with a hierarchy of neural nets. The processing assumes no underlying model for the events of interest. Rather, the system 'learns' to detect and classify faults by examination and fusion of features from training data which have known fault conditions. Results of processing real helicopter gearbox vibration data with seeded faults are shown. GRA

N93-16404# Aeronautical Research Labs., Melbourne (Australia).
MEASUREMENT OF THE DYNAMIC UNDERCARRIAGE RESPONSE OF A SIKORSKY S-70B-2 HELICOPTER: INSTRUMENTATION AND TEST METHODS: FLIGHT MECHANICS TECHNICAL MEMORANDUM
D. T. HOURIGAN, F. J. BIRD, and C. W. SUTTON Jun. 1992 32 p
(AD-A256319; ARL-FLIGHT-MECH-TM-462; DODA-AR-007-082) Avail: CASI HC A03/MF A01

The instrumentation and techniques are described which were used to measure the dynamic undercarriage response of a Royal Australian Navy S-7OB-2 Seahawk helicopter. GRA

N93-16562# Cranfield Inst. of Tech., Bedford (England). Coll. of Aeronautics.
A90 PROJECT: DESIGN OF A COMPOSITE FIN M.S. Thesis
P. D. FRIAR Apr. 1991 288 p
(ETN-92-92773) Copyright Avail: CASI HC A13/MF A03

The preliminary design of the fin for the A90 project, a civil transport airliner to be manufactured from advanced laminated fiber reinforced plastic composite materials, and which will carry a highset all moving 'T' tailplane, is presented. The fin structure was designed on the normal criteria of strength, stiffness, fatigue, and minimum weight. In addition the following factors were considered: ease of manufacture, use of standard materials, simplicity, impact requirements, accessibility and maintainability, and lightning strike protection. Air loads experienced by the fin are derived and used to produce shear force, bending moment and torque distributions for structural axes parallel and perpendicular to the swept rear spar. These were used as the basis of the structural analysis to design and size the various internal components of the fin, the spar booms, spar webs, skins, ribs and metallic fittings. The practical choice of composite layups is discussed together with the selection of suitable layups for each structural member of the fin. It is concluded that the design of a large fin structure in composite materials is a feasible proposition, and that extensive use of these materials produces worthwhile weight savings. ESA

N93-16635 ESDU International Ltd., London (England).
EXAMPLE OF STATISTICAL TECHNIQUES APPLIED TO ANALYSIS OF LANDING GROUND ROLL DISTANCE MEASUREMENTS (LINEAR REGRESSION, CORRELATION COEFFICIENT AND F-TEST) Abstract Only
Oct. 1992 8 p
(ISSN 0141-4054)
(ESDU-92021; ISBN-0-85679-826-6) Avail: ESDU

ESDU 92021 uses the analysis of a set measurements of approach speed and associated landing ground roll distance to illustrate the use of linear, two variable regression. Regression is used twice: firstly, on an empirical basis, a linear relationship is assumed between the two variables, and secondly, taking account of the physics of the maneuver, a linear relationship is assumed between the square of the approach speed and the ground roll. In both cases, the significance of the derived fit is verified using the F variance ratio test and the correlation coefficient. Both fits are found to be excellent, although the latter is clearly the better physical model. An introduction to statistical techniques for use in the analysis of aircraft performance data is given in ESDU 91017. Author

N93-16636 ESDU International Ltd., London (England).
EXAMPLE OF STATISTICAL TECHNIQUES APPLIED TO ANALYSIS OF MEASUREMENTS OF THE LANDING AIRBORNE MANOEUVRE. (MULTIPLE LINEAR REGRESSION WITH TWO INDEPENDENT VARIABLES AND ONE DEPENDENT VARIABLE.) Abstract Only
Oct. 1992 13 p
(ISSN 0141-4054)
(ESDU-92022; ISBN-0-85679-827-4) Avail: ESDU

ESDU 92022 uses the analysis of a set of measurements of screen and touchdown speed, rates of descent at the screen and touchdown, and airborne time to illustrate multiple linear regression. In this context it is usual to derive two separate correlations: the relationship between the mean rate of descent and the rates of descent at the screen and touchdown, and the relationship between the ratio and the screen speed to the touchdown speed and the rates of descent at the screen and touchdown. In both cases the significance of the derived fit is verified using the F variance ratio test. The use of the results to derive certification values of airborne distance is discussed. An introduction to statistical techniques for use in the analysis of aircraft performance data is given in ESDU 91017. Author

N93-16761*# Hampton Univ., VA. Dept. of Mass Media Arts.
THE NASA HIGH-SPEED RESEARCH PROGRAM
SHERILEE F. BEAM *In its* NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 71-74 Sep. 1992
Avail: CASI HC A01/MF A03

Since its inception, one of NASA's commitments has been to develop the technology to advance aeronautics. As such, a new High-Speed Research Program was activated to develop the technology for industry to build a High-Speed Civil Transport - a second generation Supersonic Transport (SST). The baseline for this program is the British Concorde, a major technological achievement for its time, but an aircraft which is now both technologically and economically outdated. Therefore, a second generation SST must satisfy environmental concerns and still be economically viable. In order to do this, it must have no significant effect on the ozone layer, meet Federal Air Regulation 36, Stage 3 for community noise, and have no perceptible sonic boom over populated areas. These three concerns are the focus of the research efforts in Phase 1 of the program and are the specific areas covered in the technical video report. L.R.R.

N93-16796*# Old Dominion Univ., Norfolk, VA.
MULTIDISCIPLINARY DESIGN OPTIMIZATION USING RESPONSE SURFACE ANALYSIS
RESIT UNAL *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 189-190 Sep. 1992
Avail: CASI HC A01/MF A03

Aerospace conceptual vehicle design is a complex process which involves multidisciplinary studies of configuration and technology options considering many parameters at many values. NASA Langley's Vehicle Analysis Branch (VAB) has detailed computerized analysis capabilities in most of the key disciplines required by advanced vehicle design. Given a configuration, the capability exists to quickly determine its performance and lifecycle cost. The next step in vehicle design is to determine the best settings of design parameters that optimize the performance characteristics. Typical approach to design optimization is experience based, trial and error variation of many parameters one at a time where possible combinations usually number in the thousands. However, this approach can either lead to a very long and expensive design process or to a premature termination of the design process due to budget and/or schedule pressures. Furthermore, one variable at a time approach can not account for the interactions that occur among parts of systems and among disciplines. As a result, vehicle design may be far from optimal. Advanced multidisciplinary design optimization (MDO) methods are needed to direct the search in an efficient and intelligent manner in order to drastically reduce the number of candidate designs to be evaluated. The payoffs in terms of enhanced performance and reduced cost are significant. A literature review yields two such advanced MDO methods used in aerospace design optimization; Taguchi methods and response surface methods. Taguchi methods provide a systematic and efficient method for design optimization for performance and cost. However, response surface method (RSM) leads to a better, more accurate exploration of the parameter space and to estimated optimum conditions with a small expenditure on experimental data. These two methods are described. Author

N93-16947*# McDonnell-Douglas Corp., Long Beach, CA. Development Group.
THE 1990 HIGH-SPEED CIVIL TRANSPORT STUDIES Final Report, 1 Oct. 1989 - 31 Mar. 1991
Oct. 1992 75 p
(Contract NAS1-18378; RTOP 537-01-22-01)
(NASA-CR-189618; NAS 1.26:189618; MDC-K0395-2) Avail: CASI HC A04/MF A01

This summary report contains the results of the Douglas Aircraft Company system studies related to High-Speed Civil Transports (HSCT's). The tasks were performed under an 18-month extension of NASA Langley Research Center Contract NAS1-18378. The system studies were conducted to assess the emission impact of HSCT's at design Mach numbers ranging from 1.6 to 3.2. The tasks specifically addressed an HSCT market and economic assessment, development of supersonic route networks, and an atmospheric emissions scenario. The general results indicated: (1) market projections predict sufficient passenger traffic for the 2000 to 2025 time period to support a fleet of economically viable and environmentally compatible HSCT's; (2) the HSCT route structure to minimize supersonic overland traffic can be increased by innovative routing to avoid land masses; and (3) the atmospheric emission impact on ozone would be significantly lower for Mach 1.6 operations than for Mach 3.2 operations. Author

N93-16999*# McDonnell-Douglas Corp., Long Beach, CA. Development Group.
THE 1990 HIGH-SPEED CIVIL TRANSPORT STUDIES. SUMMARY REPORT Final Report
Oct. 1992 28 p
(Contract NAS1-18378; RTOP 537-01-22-01)
(NASA-CR-189619; NAS 1.26:189619; MDC-K0395-3) Avail: CASI HC A03/MF A01

This report contains the results of the Douglas Aircraft Company system studies related to High-Speed Civil Transports (HSCT's). The tasks were performed under an 18-month extension of NASA Langley Research Center Contract NAS1-18378. The system studies were conducted to assess the emission impact of HSCT's at design Mach numbers ranging from 1.6 to 3.2. In particular,

engine cycles were assessed regarding community noise and atmospheric emissions impact, and a HSCT route structure was developed. The general results indicated the following: (1) in the Mach number range 1.6 to 2.5, the development of polymer composite and discontinuous reinforced alumnium materials is essential to ensure a minimum operational weight; (2) the HSCT route structure to minimize supersonic overland can be increased by innovative routing to avoid land masses; (3) at least two engine concepts show promise in achieving sideline stage 3 noise limits; (4) two promising low-NO(x) combustor concepts were identified; (5) the atmospheric emission impact on ozone could be significantly lower for Mach 1.6 operations than for Mach 3.2 operations; and (6) sonic boom minimization concepts are maturing at an encouraging rate. Author

N93-17219# Federal Aviation Administration, Atlantic City, NJ.
AIRCRAFT WING COMPARTMENT LINER CONCEPT TO REDUCE FUEL SPILLAGE
ROBERT F. SALMON Nov. 1992 31 p
(DOT/FAA/CT-TN92/34) Avail: CASI HC A03/MF A01

A new concept in aircraft fuel tank design is described. The concept has the potential for reducing the spillage from an aircraft fuel tank which has been ruptured during what could be considered a survivable crash. The time element is very critical for survival after a crash. By reducing the amount of fuel spilled during the first minute after the aircraft comes to rest, the probability of passenger survival can be greatly enhanced. The penalties in weight and reduction in fuel capacity resulting from installing the new containment system appear to be minor. The reduction in fuel capacity in a 707 type aircraft, for instance, would be approximately 44 gallons or 0.32 percent of total fuel capacity. Author

N93-17535# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
REVIEW OF AERONAUTICAL FATIGUE INVESTIGATIONS IN THE NETHERLANDS DURING THE PERIOD MARCH 1989 - MARCH 1991
J. B. DEJONGE 6 Mar. 1991 34 p Presented at 22d ICAF Conference, Tokyo, Japan, 20-21 May 1991
(NLR-TP-91092-U; ETN-92-92516) Avail: CASI HC A03/MF A01

Within the framework of aeronautical fatigue investigations the following are discussed: fatigue load monitoring of aircraft; test load sequences; crack propagation studies; metallic materials evaluation; full scale certification tests; fatigue of composites; aging aircraft problems; and nondestructive inspection. Where possible, applicable references are presented. ESA

N93-17562# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
FLIGHT SIMULATION AND CONSTANT AMPLITUDE FATIGUE CRACK GROWTH IN ALUMINUM-LITHIUM SHEET AND PLATE
R. J. H. WANHILL, W. G. J. THART, and L. SCHRA 24 Apr. 1991 43 p Presented at the 16th ICAF Symposium, Tokyo, Japan, May 1991 Previously announced in IAA as A93-13644 Sponsored by Netherlands Agency for Aerospace Programs
(NLR-TP-91104-U; ETN-92-92519) Avail: CASI HC A03/MF A01

Results of fatigue crack growth tests, performed to compare the modern Al-Li alloys 2090, 2091, and 8090 with the conventional damage tolerant alloys 2024 and 2324 are reviewed. These tests were done using constant amplitude and flight simulation loading. Under constant amplitude loading the Al-Li alloy crack growth behavior is often equivalent or superior to that of the conventional alloys. However, under gust spectrum loading the conventional alloys are generally better. The changes in rankings are explained from fracture surface analysis. The practical significance of the results is discussed, and guidelines for further investigation are given. ESA

N93-17564# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Military Aircraft Div.
MATHEMATICAL OPTIMIZATION: A POWERFUL TOOL FOR AIRCRAFT DESIGN
OTTO SENSBURG 28 Feb. 1992 22 p Presented at AGARD Lectures Series No. 186 on Integrated Design Analysis and Optimisation of Aircraft Structures Previously announced as N92-28474
(MBB-FE-2-S-PUB-478; ETN-92-92572) Copyright Avail: CASI HC A03/MF A01

Formal mathematical optimization methods developed during the past 10 to 15 years for the structural design of aircraft are considered. Together with reliable analysis programs like finite element methods they provide powerful tools for the structural design. They are efficient in at least two ways: producing designs that meet all specified requirements at minimum weight in one step; relieving the engineer from a time consuming search for modifications that give better results, they allow more creative design modifications. A powerful optimization code, called MBB-LAGRANGE, which uses mathematical programming and gradients to fulfill different constraints simultaneously, is considered. The application of this optimization program to the aeroelastic problems and structural design of a tailless sailplane is outlined. The enlargment of the optimization program to include also shape and size of airplanes is discussed. ESA

N93-17565# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Military Aircraft Div.
PRACTICAL ARCHITECTURE OF DESIGN OPTIMISATION SOFTWARE FOR AIRCRAFT STRUCTURES TAKING THE MBB-LAGRANGE CODE AS AN EXAMPLE
J. KRAMMER 4 Mar. 1992 19 p Presented at AGARD Lecture Series No. 186 on Integrated Design Analysis and Optimisation of Aircraft Structures Previously announced as N92-28471
(MBB-FE-251-S-PUB-479; ETN-92-92575) Copyright Avail: CASI HC A03/MF A01

The solution of design tasks in the aircraft development process using structural optimization methods is presented. The structural optimization system MBB-LAGRANGE allows the optimization of homogeneous isotropic, orthotropic, or anisotropic structures. With the simultaneous consideration of different requirements in the design of aircraft structures it is possible to reduce the number of iteration steps between design, analysis, and manufacturing. Based on finite element methods for structures and panel methods for aerodynamics, the analysis with sensitivity includes modules for static, buckling, dynamic, static aeroelastic, and flutter calculations. The optimization algorithms consists of mathematical programming methods and an optimality criteria procedure. The important link between optimization and analysis/sensitivity is the optimization model which leads to a very modular architecture. Typical application examples show the power and generality of the approach. ESA

N93-17566# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany).
MODERN HELICOPTER TECHNOLOGIES AT MBB AND THE APPLICATION IN FUTURE PROGRAMMES
WERNER REINL 1991 22 p Presented at 17th European Rotorcraft Forum, Berlin, Germany, 24-27 Sep. 1991; sponsored by DGLR Previously announced in IAA as A92-56304
(MBB-UD-0599-91-PUB; ETN-92-92576) Avail: CASI HC A03/MF A01

The history of the German helicopter activities is described. A short definition of the market needs for the helicopter technologies, based on civil and military use is given, and current activities at MBB (Messerschmitt-Boelkow-Blohm) are described. The most important technology programs covering rotor technology, vibration supression, advanced composite airframes, avionics/cockpits and flight controls are presented. The present and future helicopter project like BO108, PAH2, NH90 and ALH are discussed. An outlook concerning MBB helicopter activities is given in conclusion. ESA

N93-17567# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Helicopter Div.
MISSION ORIENTED INVESTIGATION OF HANDLING QUALITIES THROUGH SIMULATION
DIETER BRAUN, KONSTANTIN KAMPA, and DIETER SCHIMKE 1991 14 p Presented at 17th European Rotorcraft Forum, Berlin, Germany, 24-27 Sep. 1991; sponsored by DGLR Previously announced in IAA as A92-56353
(MBB-UD-0600-91-PUB; ETN-92-92577) Avail: CASI HC A03/MF A01

The methodology of simulation application in the design process of a helicopter is discussed. The simulation facility is described and the main features of the simulation model are explained. Special emphasis is laid on engine, landing gear, noise, and vibration modeling. The validation of the model was performed by use of trim values, time histories, derivatives, and frequency responses. A mission analysis is discussed using the example of an EMS mission. Exemplary investigations for the evaluation of mission effectiveness, control response behavior, and system failures are covered. ESA

N93-17569# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Helicopter Div.
INFLUENCE OF CROSS SECTION VARIATIONS ON THE STRUCTURAL BEHAVIOUR OF COMPOSITE ROTOR BLADES
HELMUT RAPP and RUDOLF WOERNDLE 1991 11 p Presented at 17th European Rotorcraft Forum, Berlin, Germany, 24-27 Sep. 1991; sponsored by DGLR Previously announced in IAA as A92-56320
(MBB-UD-0602-91-PUB; ETN-92-92579) Avail: CASI HC A03/MF A01

Structural analysis of modern helicopter rotor blades with nonhomogeneous cross sections made from nonisotropic material is considered. It is noted that variations in cross section make this a highly complicated task. The analytical engineering theory of bending is addressed, however this analysis fails to describe all the necessary effects, such as restraint warping due to cross section variations, and restraint transverse deformation due to different Poisson ratios. The Finite Element Method (FEM), (with three dimensional solid elements), is addressed. This method is found to describe influences not described by the engineering theory of bending. However, the immense effort does not allow this method in general. Combinations of suited analytical methods with numerical FEM based methods allows a cost effective and sufficient accurate analysis of these complicated structures. Results of tests of the two methods are compared and show that in general the one dimensional engineering theory of bending combined with two dimensional theories for determining the cross section properties is sufficient to describe the structural blade behavior. Tests show a good coincidence with the theoretical results. ESA

N93-17660# Naval Postgraduate School, Monterey, CA.
STATISTICAL FATIGUE ANALYSIS OF THE SH-60B SERVO BEAM RAIL COMPONENT M.S. Thesis
SALLY DEGOZZALDI Sep. 1992 86 p
(AD-A257474) Avail: CASI HC A05/MF A01

Statistical methods were researched to better understand the effect of the flight loads on the servo beam rail component of the SH-60B helicopter. The extreme value distribution and the Weibull distribution were used to model the distribution of flight loads. Specifically, the flight loads for the symmetric pullout maneuver were studied. Both models successfully represented the data, although more data are required to be fully confident in these representations. Different flight characteristics indicate that various factors such as gross weight, airspeed, and collective position effect the distribution of loads. The model runs indicate a good representation of the individual runs in fatigue life calculations. The damage calculated for the Sikorsky substantiation load run was less conservative than the model run. In addition, the maximum load of the substantiation run was only in the 45th percentile of the load distribution estimated using an extreme value distribution for loads. The damage calculated for the Sikorsky substantiation load run was more conservative than the damage calculated for the individual runs which was reduced as much as 100 times when corrected for mean load. GRA

N93-17694# Naval Postgraduate School, Monterey, CA.
AN INVESTIGATION OF TWO-PROPELLER TILT WING V/STOL AIRCRAFT FLIGHT CHARACTERISTICS M.S. Thesis
WILLIAM J. NIEUSMA, JR. 1992 89 p
(AD-A257751) Avail: CASI HC A05/MF A01

The results of a two-propeller tilt wing aircraft static stability and performance simulation utilizing a NASA-Ames computer code, Tilt Wing Application General (TWANG), are presented with comparisons to actual test flight data. The Canadair CL-84 tilt wing aircraft was used as a model for the geometric data utilized by the computer simulation. Aerodynamic data for the simulation were obtained from previous NASA Ames research related to a four-propeller model. Variables used included a wide range of parameters associated with flight conditions from hovering flight to maximum cruise speeds at several different altitudes and wing tilt configurations. Longitudinal pitch stability was the driving factor in determining aircraft static stability for the various flight conditions. Results of the simulation indicate that the TWANG computer code provides an accurate prediction of both generic and specific tilt wing aircraft static pitch performance characteristics, as well as the additional capability of providing the required mathematical parameters for incorporation into the NASA Ames Vertical Motion Simulator as software inputs. GRA

N93-17711*# Purdue Univ., West Lafayette, IN. School of Aeronautics and Astronautics.
THE DESIGN OF A LONG RANGE MEGATRANSPORT AIRCRAFT Final Report, Aug. 1991 - Jun. 1992
TERRENCE A. WEISSHAAR and CARL L. ALLEN 30 Jun. 1992 17 p
(Contract NASW-4435)
(NASA-CR-192077; NAS 1.26:192077) Avail: CASI HC A03/MF A01

During the period from August 1991 - June 1992 two design classes at Purdue University participated in the design of a long range, high capacity transport aircraft, dubbed the megatransport. Thirteen Purdue design teams generated RFP's that defined passenger capability and range, based upon team perception of market needs and infrastructure constraints. Turbofan engines were designed by each group to power these aircraft. The design problem and the variety of solutions developed are described in an attached paper. Author

N93-17802*# Worcester Polytechnic Inst., MA.
NASA ADVANCED DESIGN PROGRAM: ANALYSIS, DESIGN, AND CONSTRUCTION OF A SOLAR POWERED AIRCRAFT B.S. Thesis
AGNES CHAN, KRISTIN CONLEY, CHRISTIAN T. JAVORSKI, KWOK-HUNG CHEUNG, PAUL M. CRIVELLI, NANCY P. TORREY, and MICHAEL L. TRAVER 1992 112 p
(Contract NASW-4435)
(NASA-CR-192040; NAS 1.26:192040) Avail: CASI HC A06/MF A02

Increase in energy demands coupled with rapid depletion of natural energy resources have deemed solar energy as the most logical alternative source of power. The major objective of this project was to build a solar powered remotely controlled aircraft to demonstrate the feasibility of solar energy as an effective, alternate source of power. The final design was optimized for minimum weight and maximum strength of the structure. These design constraints necessitated a carbon fiber composite structure. Surya is a lightweight, durable aircraft capable of achieving level flight powered entirely by solar cells. Author

N93-17803*# Notre Dame Univ., IN. Dept. of Aerospace and Mechanical Engineering.
EXODUS: PRIME MOVER Air transport system design simulation
NIKKOL BAUER, PETE CONWELL, MATT JOHNSON, WENDY

SHIELDS, TIM THORNTON, ROB TOKARZ, and RICH MCMANUS May 1992 127 p Sponsored by NASA
(NASA-CR-192051; NAS 1.26:192051) Avail: CASI HC A07/MF A02

The Exodus Prime Mover is an overnight package delivery aircraft designed to serve the Northern Hemisphere of Aeroworld. The preliminary design goals originated from the desire to produce a large profit. The two main driving forces throughout the design process were first to reduce the construction man-hours by simplifying the aircraft design, thereby decreasing the total production cost of the aircraft. The second influential factor affecting the design was minimizing the fuel cost during cruise. The lowest fuel consumption occurs at a cruise velocity of 30 ft/s. Overall, it was necessary to balance the economic benefits with the performance characteristics in order to create a profitable product that meets all specified requirements and objectives.
Author

N93-17804*# Ohio State Univ., Cleveland.
HYPERSONIC RECONNAISSANCE AIRCRAFT Scarlet 2 design team
TIM BULK, DAVID CHIARINI, KEVIN HILL, BOB KUNSZT, CHRIS ODGEN, and BON TRUONG 1992 80 p Sponsored by NASA
(NASA-CR-192049; NAS 1.26:192049) Avail: CASI HC A05/MF A01

A conceptual design of a hypersonic reconnaissance aircraft for the U.S. Navy is discussed. After eighteen weeks of work, a waverider design powered by two augmented turbofans was chosen. The aircraft was designed to be based on an aircraft carrier and to cruise 6,000 nautical miles at Mach 4;80,000 feet and above. As a result the size of the aircraft was only allowed to have a length of eighty feet, fifty-two feet in wingspan, and roughly 2,300 square feet in planform area. Since this is a mainly cruise aircraft, sixty percent of its 100,000 pound take-off weight is JP fuel. At cruise, the highest temperature that it will encounter is roughly 1,100 F, which can be handled through the use of a passive cooling system.
Author

N93-17850# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
IMPROVING MILITARY TRANSPORT AIRCRAFT THROUGH HIGHLY INTEGRATED ENGINE-WING DESIGN
A. LARDELLIER 1991 16 p Presented at AGARD Conference on Progress in Military Airlift
(DS-1607; ETN-93-93386) Avail: CASI HC A03/MF A01

The attraction of a 'half way approach' between turbofan (easy installation) and propfan (light thermopropulsive efficiency) concepts are considered. Results of studies which have shown the interest of very large by pass ratio engines to power long range airliners, at cruise speed exceeding Mach 0.8 are discussed, together with benefit in terms of installed specific fuel consumption, that can be expected for the Future Large Aircraft (FLA), cruising at Mach 0.75. Compared to an equivalent turbofan, a very large bypass engine can deliver a higher thrust during take off, thus improving the high lift capability of the aircraft. Taking into account that a conventional front fan engine is likely to show a large Radar Cross Section (RCS), and that this problem would have to be addressed for FLA, the engine preferred concept is a ducted aft contrafan. The resulting high hub tip ratio fan flow path, combined with slow rotating composite fan blades is indeed a good approach towards reduction of the engine RCS. In order to minimize the extra weight due to the long duct, a highly integrated engine wing design is proposed, offering a reduced friction drag; particular attention is paid to maintenance and transportation problems.
ESA

N93-17888# Ohio State Univ., Columbus. Design Group Gray 2.
A MANNED HYPERSONIC RECONNAISSANCE VEHICLE WHICH DOES NOT REQUIRE AIRBORNE FUELING
MIKE COLLINS, TRICIA CORCORAN, TIMOTHY HIGGINS, DAVE KAZARIAN, JOE KUBASEK, MIKE LEWIS, DEANNA ROLL, and CHAD SCHERGER 1992 84 p
Avail: CASI HC A05/MF A01

This report discusses and presents a preliminary design for a manned hypersonic reconnaissance vehicle which does not require airborne refueling. This vehicle will have a range of 12000 nautical miles and will cruise at a speed of Mach 4 and an altitude of 80000 feet. The design process utilized computer programs such as HASA and MAXWARP. An elementary economic analysis is presented. Finally, areas which deserve further study are discussed.
Author

N93-17893# Air Force Inst. of Tech., Wright-Patterson AFB, OH.
CFD-BASED APPROXIMATION CONCEPTS FOR AERODYNAMIC DESIGN OPTIMIZATION WITH APPLICATION TO A 2-D SCRAMJET VEHICLE Ph.D. Thesis
PETER D. MCQUADE 1992 102 p
(AD-A258084; AFIT/CI/CIA-92-019D) Avail: CASI HC A06/MF A02

Approximation concepts, which are gaining popularity in structural optimization, offer the potential of providing the accuracy of a high-fidelity 'detailed' analysis model at greatly reduced computational cost. This is because the detailed model is used only to 'fine tune' a much cheaper 'approximate' model which is then used by the optimizer. The test problem is the optimization of a 2-D scramjet vehicle flying at Mach 6.0 at 30 km altitude. The objective function is net thrust. The following approximation concepts were used: Taylor series approximation to wall pressures and inlet plane flow properties; and Haftka's Global-Local Approximation (GLA) applied to the same variables. It is shown that a modification must be made to the formulation of the approximation concepts to allow for the changing CFD grids. All correction factors are applied not to the CFD grid points, but to a constant, dense, non-dimensionalized 'correction point' grid system. In flow regions devoid of shocks or other discontinuous phenomena (such as in the scramjet nozzle region), this is the only major modification needed.
GRA

N93-17958 ESDU International Ltd., London (England).
PITCHING MOMENT OF LOW ASPECT RATIO WING-BODY COMBINATIONS UP TO HIGH ANGLES OF ATTACK AT SUPERSONIC SPEEDS
Dec. 1992 13 p
(ISSN 0141-397X)
(ESDU-92043; ISBN-0-85679-853-3) Avail: ESDU

ESDU 92043 presents a method based on evaluating the various contributions to the pitching moment, namely, those due to the body alone and the wing alone, together with interference components due to the effect of the wing on the body, the body on the wing and the body vortices on the wing. It assumes the body alone pitching moment may be combined with the products of the normal forces and centers of pressure of the wing along and interference components. The body alone pitching moment is obtained from ESDU 89014 (or the program of ESDU 90034), the wing-body mutual interference factors from ESDU 91007, and the body vortex interference factors from ESDU 91042. The wing center of pressure and normal force are evaluated following ESDU 90013 and the center of pressure of the carry-over load from the wing to the body is taken to be its aerodynamic center determined from ESDU 92024. The method applies to delta, cropped delta or rectangular thin, sharp-edged wings without camber or twist mid-set on an axisymmetric forebody-cylinder combination for Mach numbers of 1.2 to 5, taper ratios of 0 to 1, and aspect ratios of 0.2 to 4 at angles of attack up to 60 degrees. It was tested against experimental data drawn from the literature and was found to be accurate within 0.03 of body length for body fineness ratios of 10 to 20 and diameter to wing span ratios of 2.1 to 8.
ESDU

N93-17972*# Auburn Univ., AL. Dept. of Aerospace Engineering.
DESIGN OF THE ADVANCED REGIONAL AIRCRAFT, THE DART-75

STEVE ELLIOTT, JASON GISLASON, MARK HUFFSTETLER, JON MANN, ASHLEY WITHERS, and MARK ZIMMERMAN Jun. 1992 88 p
(Contract NASW-4435)
(NASA-CR-192044; NAS 1.26:192044) Avail: CASI HC A05/MF A01

This design analysis is intended to show the capabilities of the DART-75, a 75 passenger medium-range regional transport. Included are the detailed descriptions of the structures, performance, stability and control, weight and balance, and engine design. The design should allow for the DART to become the premier regional aircraft of the future due to some advanced features like the canard, semi-composite construction, and advanced engines. Author

N93-17974*# California Polytechnic State Univ., San Luis Obispo. Dept. of Aeronautical Engineering.
MM-122: HIGH SPEED CIVIL TRANSPORT
BILL DEMAREST, KURT ANDERS, JOHN MANCHEC, ERIC YANG, DAN OVERGAARD, and MIKE KALKWARF Jun. 1992 107 p
(Contract NASW-4435)
(NASA-CR-192011; NAS 1.26:192011) Avail: CASI HC A06/MF A02

The rapidly expanding Pacific Rim market along with other growing markets indicates that the future market potential for a high speed civil transport is great indeed. The MM-122 is the answer to the international market desire for a state of the art, long range, high speed civil transport. It will carry 250 passengers a distance of 5200 nm at over twice the speed of sound. The MM-122 is designed to incorporate the latest technologies in the areas of control systems, propulsions, aerodynamics, and materials. The MM-122 will accomplish these goals using the following design parameters. First, a double delta wing planform with highly swept canards and an appropriately area ruled fuselage will be incorporated to accomplish desired aerodynamic characteristics. Propulsion will be provided by four low bypass variable cycle turbofan engines. A quad-redundant fly-by-wire flight control system will be incorporated to provide appropriate static stability and level 1 handling qualities. Finally, the latest in conventional metallic and modern composite materials will be used to provide desired weight and performance characteristics. The MM-122 incorporates the latest in technology and cost minimization techniques to provide a viable solution to this future market potential. Author

N93-17976*# California Polytechnic State Univ., San Luis Obispo. Dept. of Aeronautical Engineering.
PHOENIX: PRELIMINARY DESIGN OF A HIGH SPEED CIVIL TRANSPORT
JOSEPH AGUILAR, STEVEN DAVIS, BRIAN JETT, LESLIE RINGO, JOHN STOB, and BILL WOOD 9 Jun. 1992 120 p
(Contract NASW-4435)
(NASA-CR-192024; NAS 1.26:192024) Avail: CASI HC A06/MF A02

The goal of the Phoenix Design Project was to develop a second generation high speed civil transport (HSCT) that will meet the needs of the traveler and airline industry beginning in the 21st century. The primary emphasis of the HSCT is to take advantage of the growing needs of the Pacific Basin and the passengers who are involved in that growth. A passenger load of 150 persons, a mission range of 5150 nautical miles, and a cruise speed of Mach 2.5 constitutes the primary design points of this HSCT. The design concept is made possible with the use of a well designed double delta wing and four mixed flow engines. Passenger comfort, compatibility with existing airport infrastructure, and cost competitive with current subsonic aircraft make the Phoenix a viable aircraft for the future. Author

N93-17977*# Case Western Reserve Univ., Cleveland, OH. Dept. of Mechanical and Aerospace Engineering.
TESSERACT: SUPERSONIC BUSINESS TRANSPORT
ELI RESHOTKO and GARY GARBINSKI 1992 74 p
(Contract NASW-4435)
(NASA-CR-192072; NAS 1.26:192072) Avail: CASI HC A04/MF A01

This year, the senior level Aerospace Design class at Case Western Reserve University developed a conceptual design of a supersonic business transport. Due to the growing trade between Asia and the United States, a transpacific range has been chosen for the aircraft. A Mach number of 2.2 was chosen too because it provides reasonable block times and allows the use of a large range of materials without a need for active cooling. A payload of 2500 lbs. has been assumed corresponding to a complement of nine (passengers and crew) plus some light cargo. With these general requirements set, the class was broken down into three groups. The aerodynamics of the aircraft were the responsibility of the first group. The second developed the propulsion system. The efforts of both the aerodynamics and propulsion groups were monitored and reviewed for weight considerations and structural feasibility by the third group. Integration of the design required considerable interaction between the groups in the final stages. The fuselage length of the final conceptual design was 107.0 ft. while the diameter of the fuselage was 7.6 ft. The delta wing design consisted of an aspect ratio of 1.9 with a wing span of 47.75 ft and midcord length of 61.0 ft. A SNEMCA MCV 99 variable-cycle engine design was chosen for this aircraft. Author

N93-18017*# Auburn Univ., AL. Dept. of Aerospace Engineering.
EAGLE RTS: A DESIGN FOR A REGIONAL TRANSPORT AIRCRAFT
PAUL BRYER, JON BUCKLES, PAUL LEMKE, and KIRK PEAKE 1 Jun. 1992 64 p
(Contract NASW-4435)
(NASA-CR-192032; NAS 1.26:192032) Avail: CASI HC A04/MF A01

This university design project concerns the Eagle RTS (Regional Transport System), a 66 passenger, twin turboprop aircraft with a range of 836 nautical miles. It will operate with a crew of two pilots and two flight attendents. This aircraft will employ the use of aluminum alloys and composite materials to reduce the aircraft weight and increase aerodynamic efficiency. The Eagle RTS will use narrow body aerodynamics with a canard configuration to improve performance. Leading edge technology will be used in the cockpit to improve flight handling and safety. The Eagle RTS propulsion system will consist of two turboprop engines with a total thrust of approximately 6300 pounds, 3150 pounds thrust per engine, for the cruise configuration. The engines will be mounted on the aft section of the aircraft to increase passenger safety in the event of a propeller failure. Aft mounted engines will also increase the overall efficiency of the aircraft by reducing the aircraft's drag. The Eagle RTS is projected to have a takeoff distance of approximately 4700 feet and a landing distance of 6100 feet. These distances will allow the Eagle RTS to land at the relatively short runways of regional airports. Author

N93-18037*# Ohio State Univ., Cleveland. Dept. of Aeronautical and Astronautical Engineering.
ADVANCED HYPERSONIC AIRCRAFT DESIGN
ROB UTZINGER, HANS-JOACHIM BLANK, CRAIG COX, GREG HARVEY, MIKE MCKEE, DAVE MOLNAR, GREG NAGY, and STEVE PETERSEN 1 Jun. 1992 87 p Sponsored by NASA. Lewis Research Center and GE
(NASA-CR-192046; NAS 1.26:192046) Avail: CASI HC A05/MF A01

The objective of this design project is to develop the hypersonic reconnaissance aircraft to replace the SR-71 and to complement existing intelligence gathering devices. The initial design considerations were to create a manned vehicle which could complete its mission with at least two airborne refuelings. The aircraft must travel between Mach 4 and Mach 7 at an altitude of 80,000 feet for a maximum range of 12,000 nautical miles. The vehicle should have an air breathing propulsion system at cruise. With a crew of two, the aircraft should be able to take off and land on a 10,000 foot runway, and the yearly operational costs were not to exceed $300 million. Finally, the aircraft should exhibit

stealth characteristics, including a minimized radar cross-section (RCS) and a reduced sonic boom. The technology used in this vehicle should allow for production between the years 1993 and 1995. Author

N93-18042 ESDU International Ltd., London (England).
ENERGY METHOD FOR ANALYSIS OF MEASURED AIRSPEED CHANGE IN LANDING AIRBORNE MANOEUVRE
Dec. 1992 21 p
(ISSN 0141-4054)
(ESDU-92020; ISBN-0-85679-825-8) Avail: ESDU

ESDU 92020 gives a method that correlates measurements of airspeed changed in the airborne maneuver on the basis of energy considerations to yield changes in lift and in drag-minus-thrust between screen and touchdown. The method applies to fixed wing aircraft and can be applied to any set of flight test measurements although it is most effective when the landings have a common 'style'. Examples would be those flown for civil certification purposes, or those representative of operational practice. The use of the correlation to calculate touchdown speed from a knowledge of the airborne time and the screen speed is explained, and methods of calculating the airborne time are suggested. The prediction of the airborne distance from the speeds and airborne time is straightforward in still air, but the effect of a steady wind, and a wind gradient, is considered. A worked example illustrates the use of the method, and the scatter on some points is investigated in relation to the 'style'. Examples of the application of the method to particular sets of test data are shown for jet-, fan- and propeller-driven civil and military aeroplanes and to an unpowered aircraft. They contain large ranges of approach angle, speed, power-cut height and landing 'style'. ESDU

N93-18049*# California Polytechnic State Univ., San Luis Obispo. Dept. of Aeronautical Engineering.
PROPOSAL AND PRELIMINARY DESIGN FOR A HIGH SPEED CIVIL TRANSPORT AIRCRAFT. SWIFT: A HIGH SPEED CIVIL TRANSPORT FOR THE YEAR 2000
AEROBEL BANUELOS, MARIA L. CABALLERO, RICHARD S. FIELDS, JR., MARTHA E. LEDESMA, LYNNE A. MURAKAMI, JOE T. REYES, and BRYAN W. WESTRA 9 Jun. 1992 103 p
(Contract NASW-4435)
(NASA-CR-192023; NAS 1.26:192023) Avail: CASI HC A06/MF A02

To meet the needs of the growing passenger traffic market in light of an aging subsonic fleet, a new breed of aircraft must be developed. The Swift is an aircraft that will economically meet these needs by the year 2000. Swift is a 246 passenger, Mach 2.5, luxury airliner. It has been designed to provide the benefit of comfortable, high speed transportation in a safe manner with minimal environmental impact. This report will discuss the features of the Swift aircraft and establish a solid, foundation for this supersonic transport of tomorrow. Author

N93-18054*# California Polytechnic State Univ., San Luis Obispo. Senior Design Team.
TBD(EXP 3)
JIM BAUGHAN, DAVID CALTA, VICTOR CROSS, MOZHI HABASHI, DONOVAN MATHIAS, and PATTI NORTHRUP 1992 100 p
(Contract NASW-4435)
(NASA-CR-192075; NAS 1.26:192075) Avail: CASI HC A05/MF A02

When asked by the Aeronautical Engineering staff to design a viable supersonic commercial transport, most of the students were well aware that Boeing, McDonnell Douglas, and other aircraft companies had been studying a cadre of transports for more than 30 years and had yet to present a viable aircraft. In the spirit of aviation progress and with much creative license, the TBD design team spearheaded the problem with the full intention of presenting a marketable high speed civil transport in spring of 1992. The project commenced with various studies of future market demands. With the market expansion of American business overseas, the airline industry projects a boom of over 200 million passengers by the year 2000. This will create a much higher demand for time efficient and cost effective inter-continental travel; this is the challenge of the high speed civil transport. The TBD(exp 3), a 269 passenger, long-range civil transport was designed to cruise at Mach 3.0 utilizing technology predicted to be available in 2005. Unlike other contemporary commercial airplane designs, the TBD(exp 3) incorporates a variable geometry wing for optimum performance. This design characteristic enabled the TBD(exp 3) to be efficient in both subsonic and supersonic flight. The TBD(exp 3) was designed to be economically viable for commercial airline purchase, be comfortable for passengers, meet FAR Part 25, and the current FAR 36 Stage 3 noise requirements. The TBD(exp 3) was designed to exhibit a long service life, maximize safety, ease of maintenance, as well as be fully compatible with all current high-traffic density airport facilities. Author

N93-18055*# California Polytechnic State Univ., San Luis Obispo. Dept. of Aeronautical Engineering.
THE EDGE SUPERSONIC TRANSPORT Preliminary Design Report
ROXANA AGOSTA, DUSHAN BILBIJA, MARC DEUTSCH, DAVID GALLANT, DON ROSE, GENE SHREVE, DAVID SMARIO, and BRIAN SUFFREDINI 1992 126 p
(Contract NASW-4435)
(NASA-CR-192074; NAS 1.26:192074) Avail: CASI HC A07/MF A02

As intercontinental business and tourism volumes continue their rapid expansion, the need to reduce travel times becomes increasingly acute. The Edge Supersonic Transport Aircraft is designed to meet this demand by the year 2015. With a maximum range of 5750 nm, a payload of 294 passengers and a cruising speed of $M = 2.4$, The Edge will cut current international flight durations in half, while maintaining competitive first class, business class, and economy class comfort levels. Moreover, this transport will render a minimal impact upon the environment, and will meet all Federal Aviation Administration Part 36, Stage III noise requirements. The cornerstone of The Edge's superior flight performance is its aerodynamically efficient, dual-configuration design incorporating variable-geometry wingtips. This arrangement combines the benefits of a high aspect ratio wing at takeoff and low cruising speeds with the high performance of an arrow-wing in supersonic cruise. And while the structural weight concerns relating to swinging wingtips are substantial, The Edge looks to ever-advancing material technologies to further increase its viability. Heeding well the lessons of the past, The Edge design holds economic feasibility as its primary focus. Therefore, in addition to its inherently superior aerodynamic performance, The Edge uses a lightweight, largely windowless configuration, relying on a synthetic vision system for outside viewing by both pilot and passengers. Additionally, a fly-by-light flight control system is incorporated to address aircraft supersonic cruise instability. The Edge will be produced at an estimated volume of 400 aircraft and will be offered to airlines in 2015 at $167 million per transport (1992 dollars). Author

N93-18056*# Notre Dame Univ., IN. Dept. of Aerospace and Mechanical Engineering.
HERMES CX-7: AIR TRANSPORT SYSTEM DESIGN SIMULATION Final Design Proposal
BRIAN AMER, JOHN BARTER, JAY COLUCCI, CARYN FOLEY, JAMES KOCKLER, DAVID RAPP, and MATTHEW ZEIGER May 1992 121 p Sponsored in cooperation with Boeing Commercial Airplane Co.
(Contract NASW-4435)
(NASA-CR-192082; NAS 1.26:192082) Avail: CASI HC A06/MF A02

The Hermes CX-7 has been designed to service the overnight parcel package delivery needs of the cities of Aeroworld as determined in the G-Dome Enterprises market survey. The design optimization centers on the prime goal of servicing the needs of these cities as efficiently and profitably as possible. The greatest factors which affect the design of an aircraft for the mission outlined in the Request for Proposal are cost, construction feasibility and

effectiveness of the design. Other influencing factors are given by the constraints of the market, including a maximum takeoff and landing distance of 60 feet, storage capability in a container of size 5 ft. x 3 ft. x 2 ft., cargo packages of 2 inch and 4 inch cubes, and ability to turn with a radius no larger than 60 feet. Safety considerations such as flying at or below Mach one (30 ft/s) and controllability and maintainability of the aircraft must also be designed into the aircraft. Another influential factor is the efficiency of the aircraft which involves optimizations and tradeoffs of such factors as weight, lifting surface sizing, structural redundancy, and material costs. Author

N93-18059*# California Polytechnic State Univ., San Luis Obispo. Dept. of Aeronautical Engineering.
A SECOND-GENERATION HIGH SPEED CIVIL TRANSPORT: STINGRAY
SEAN ENGDAHL, KEVIN LOPES, ANGELEN NGAN, JOSEPH PERRIN, MARCUS PHIPPS, BLAKE WESTMAN, and URN YEO
1992 116 p
(Contract NASW-4435)
(NASA-CR-192022; NAS 1.26:192022) Avail: CASI HC A06/MF A02

The Stingray is the second-generation High Speed Civil Transport (HSCT) designed for the 21st Century. This aircraft is designed to be economically viable and environmentally sound transportation competitive in markets currently dominated by subsonic aircraft such as the Boeing 747 and upcoming McDonnell Douglas MD-12. With the Stringray coming into service in 2005, a ticket price of 21 percent over current subsonic airlines will cover operational costs with a 10 percent return on investment. The cost per aircraft will be $202 million with the Direct Operating Cost equal to $0.072 per mile per seat. This aircraft has been designed to be a realistic aircraft that can be built within the next ten to fifteen years. There was only one main technological improvement factor used in the design, that being for the engine specific fuel consumption. The Stingray, therefore, does not rely on technology that does not exist. The Stingray will be powered by four mixed flow turbofans that meet both nitrous oxide emissions and FAR 36 Stage 3 noise regulations. It will carry 250 passengers a distance of 5200 nautical miles at a speed of Mach 2.4. The shape of the Stingray, while optimized for supersonic flight, is compatible with all current airline facilities in airports around the world. As the demand for economical, high-speed flight increases, the Stingray will be ready and able to meet those demands. Author

N93-18060*# California Polytechnic State Univ., San Luis Obispo. Cones of Silence Design Group.
THE TROJAN
1992 120 p
(Contract NASW-4435)
(NASA-CR-192013; NAS 1.26:192013) Avail: CASI HC A06/MF A02

The Trojan is the culmination of thousands of engineering person-hours by the Cones of Silence Design Team. The goal was to design an economically and technologically viable supersonic transport. The Trojan is the embodiment of the latest engineering tools and technology necessary for such an advanced aircraft. The efficient design of the Trojan allows for supersonic cruise of Mach 2.0 for 5,200 nautical miles, carrying 250 passengers. The per aircraft price is placed at $200 million, making the Trojan a very realistic solution for tomorrows transportation needs. The following is a detailed study of the driving factors that determined the Trojan's super design. Author

N93-18061*# California Polytechnic State Univ., San Luis Obispo. Opus 0-001 Design Team.
PRELIMINARY DESIGN OF A HIGH SPEED CIVIL TRANSPORT: THE OPUS 0-001
1992 103 p
(Contract NASW-4435)
(NASA-CR-192018; NAS 1.26:192018) Avail: CASI HC A06/MF A02

Based on research into the technology and issues surrounding the design, development, and operation of a second generation High Speed Civil Transport, HSCT, the Opus 0-001 team completed the preliminary design of a sixty passenger, three engine aircraft. The design of this aircraft was performed using a computer program which the team wrote. This program automatically computed the geometric, aerodynamic, and performance characteristic of an aircraft whose preliminary geometry was specified. The Opus 0-001 aircraft was designed for a cruise Mach number of 2.2, a range of 4,700 nautical miles and its design was based in current or very near term technology. Its small size was a consequence of an emphasis on a profitable, low cost program, capable of delivering tomorrow's passengers in style and comfort at prices that make it an attractive competitor to both current and future subsonic transport aircraft. Several hundred thousand cases of Cruise Mach number, aircraft size and cost breakdown were investigated to obtain costs and revenues for which profit was calculated. The projected unit flyaway cost was $92.0 million per aircraft. Author

N93-18063*# Notre Dame Univ., IN. Dept. of Aerospace and Mechanical Engineering.
ARROW 227: AIR TRANSPORT SYSTEM DESIGN SIMULATION Final Design Proposal
MICHAEL BONTEMPI, DAVE BOSE, GEORGEANN BROPHY, TIMOTHY CASHIN, MICHAEL KANARIOS, STEVE RYAN, and TIMOTHY PETERSON May 1992 118 p Sponsored in cooperation with Boeing Commercial Airplane Co.
(Contract NASW-4435)
(NASA-CR-192053; NAS 1.26:192053) Avail: CASI HC A06/MF A02

The Arrow 227 is a student-designed commercial transport for use in a overnight package delivery network. The major goal of the concept was to provide the delivery service with the greatest potential return on investment. The design objectives of the Arrow 227 were based on three parameters; production cost, payload weight, and aerodynamic efficiency. Low production cost helps to reduce initial investment. Increased payload weight allows for a decrease in flight cycles and, therefore, less fuel consumption than an aircraft carrying less payload weight and requiring more flight cycles. In addition, fewer flight cycles will allow a fleet to last longer. Finally, increased aerodynamic efficiency in the form of high L/D will decrease fuel consumption. Author

N93-18064*# Arizona State Univ., Tempe.
OPTIMUM DESIGN OF HIGH SPEED PROP-ROTORS
ADITI CHATTOPADHYAY 12 Oct. 1992 34 p
(Contract NAG2-771)
(NASA-CR-190915; NAS 1.26:190915) Avail: CASI HC A03/MF A01

The objective of this research is to develop optimization procedures to provide design trends in high speed prop-rotors. The necessary disciplinary couplings are all considered within a closed loop optimization process. The procedures involve the consideration of blade aeroelastic, aerodynamic performance, structural and dynamic design requirements. Further, since the design involves consideration of several different objectives, multiobjective function formulation techniques are developed.

N93-18065*# Arizona State Univ., Tempe. Dept. of Aerospace and Mechanical Engineering.
DESIGN OF HIGH SPEED PROPROTORS USING MULTIOBJECTIVE OPTIMIZATION TECHNIQUES
THOMAS R. MCCARTHY and ADITI CHATTOPADHYAY *In its* Optimum Design of High Speed Prop-Rotors 17p 12 Oct. 1992
(Contract NAG2-771)
Avail: CASI HC A03/MF A01

An integrated, multiobjective optimization procedure is developed for the design of high speed proprotors with the coupling of aerodynamic, dynamic, aeroelastic, and structural criteria. The objectives are to maximize propulsive efficiency in high speed cruise and rotor figure of merit in hover. Constraints are imposed on rotor blade aeroelastic stability in cruise and on total blade

weight. Two different multiobjective formulation procedures, the Min summation of beta and the K-S function approaches are used to formulate the two-objective optimization problems. Author

N93-18066*# Arizona State Univ., Tempe. Dept. of Mechanical and Aerospace Engineering.
OPTIMUM DESIGN OF HIGH SPEED PROP ROTORS INCLUDING THE COUPLING OF PERFORMANCE, AEROELASTIC STABILITY AND STRUCTURES
ADITI CHATTOPADHYAY, THOMAS R. MCCARTHY, and JOHN F. MADDEN, III (National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.) *In its* Optimum Design of High Speed Prop-Rotors 13 p 12 Oct. 1992
(Contract NAG2-771)
Avail: CASI HC A03/MF A01

An optimization procedure is developed for the design of high speed prop-rotors to be used in civil tiltrotor applications. The goal is to couple aerodynamic performance, aeroelastic stability, and structural design requirements inside a closed-loop optimization procedure. The objective is to minimize the gross weight and maximize the propulsive efficiency in high speed cruise. Constraints are imposed on the rotor aeroelastic stability in both hover and cruise and rotor figure of merit in hover. Both structural and aerodynamic design variables are used. Author

N93-18131# Manchester Univ. (England). Aeronautical Engineering Group.
AIRCRAFT TURNS INTO AND DOWN WIND
A. W. BLOY and K. A. LEA 18 Feb. 1992 13 p
(AERO-REPT-9201; ETN-93-93002) Avail: CASI HC A03/MF A01

An explanation of the effects of airspeed on an aircraft when tuning into or down wind is presented. By considering two reference frames, one fixed to the ground and one moving with the wind, it was shown that the airspeed of an aircraft in a banked turn without sideslip is unaffected by the wind or direction. The forces acting on the aircraft are the same with or without wind so that the pilot experiences the same acceleration and applies the same control movements. The flight path relative to the wind remains circular as in still air but is distorted relative to the ground. The aircraft ground speed increases in a turn downwind and decreases in a turn upwind, while airspeed remains constant. In terms of airspeed there is therefore no advantage in performing a quick turn into wind. ESA

N93-18155*# Ohio State Univ., Columbus. Dept. of Aerospace.
SR-SCARLET 1: PEREGRIN
MANOJ TANDON, JOSEPH C. ZUPPARDO, JAMES JOHNSON, MIKE KILIAN, NORMAN SCHACHT, DIANE FLOWERS, GREG ZORN, and CHAD BROWN 26 Jan. 1993 112 p
(Contract NASW-4435)
(NASA-CR-192048; NAS 1.26:192048) Avail: CASI HC A06/MF A02

This report presents a reconnaissance aircraft with a lifting body configuration. The aircraft is capable of flying a distance of 6000 nmi at Mach 5 with a payload of 7500 pounds. The aircraft does not require a runway for takeoff for it is air launched from a carrier aircraft. Specifically this report addresses the areas of external aerodynamics, cost, thermal protection systems, propulsion, stability and control, and materials. Each area is represented by a separate section. This allows for selective reading. Author

N93-18161*# California State Polytechnic Univ., Pomona. Dept. of Aerospace Engineering.
HIGH SPEED CIVIL TRANSPORT
1991 108 p
(Contract NASW-4435)
(NASA-CR-192041; NAS 1.26:192041) Avail: CASI HC A06/MF A02

This report discusses the design and marketability of a next generation supersonic transport. Apogee Aeronautics Corporation has designated its High Speed Civil Transport (HSCT): Supercruiser HS-8. Since the beginning of the Concorde era, the general consensus has been that the proper time for the introduction of a next generation Supersonic Transport (SST) would depend upon the technical advances made in the areas of propulsion (reduction in emissions) and material composites (stronger, lighter materials). It is believed by many in the aerospace industry that these beforementioned technical advances lie on the horizon. With this being the case, this is the proper time to begin the design phase for the next generation HSCT. The design objective for a HSCT was to develop an aircraft that would be capable of transporting at least 250 passengers with baggage at a distance of 5500 nmi. The supersonic Mach number is currently unspecified. In addition, the design had to be marketable, cost effective, and certifiable. To achieve this goal, technical advances in the current SST's must be made, especially in the areas of aerodynamics and propulsion. As a result of these required aerodynamic advances, several different supersonic design concepts were reviewed. Author

N93-18166*# California Polytechnic State Univ., San Luis Obispo. Dept. of Aeronautical Engineering.
RTJ-303: VARIABLE GEOMETRY, OBLIQUE WING SUPERSONIC AIRCRAFT
ALBERT ANTARAN, HAILU BELETE, MARK DRYZMKOWSKI, JAMES HIGGINS, ALAN KLENK, and LISA RIENECKER 29 May 1992 92 p
(Contract NASW-4435)
(NASA-CR-192054; NAS 1.26:192054) Avail: CASI HC A05/MF A01

This document is a preliminary design of a High Speed Civil Transport (HSCT) named the RTJ-303. It is a 300 passenger, Mach 1.6 transport with a range of 5000 nautical miles. It features four mixed-flow turbofan engines, variable geometry oblique wing, with conventional tail-aft control surfaces. The preliminary cost analysis for a production of 300 aircraft shows that flyaway cost would be 183 million dollars (1992) per aircraft. The aircraft uses standard jet fuel and requires no special materials to handle aerodynamic heating in flight because the stagnation temperatures are approximately 130 degrees Fahrenheit in the supersonic cruise condition. It should be stressed that this aircraft could be built with today's technology and does not rely on vague and uncertain assumptions of technology advances. Included in this report are sections discussing the details of the preliminary design sequence including the mission to be performed, operational and performance constraints, the aircraft configuration and the tradeoffs of the final choice, wing design, a detailed fuselage design, empennage design, sizing of tail geometry, and selection of control surfaces, a discussion on propulsion system/inlet choice and their position on the aircraft, landing gear design including a look at tire selection, tip-over criterion, pavement loading, and retraction kinematics, structures design including load determination, and materials selection, aircraft performance, a look at stability and handling qualities, systems layout including location of key components, operations requirements maintenance characteristics, a preliminary cost analysis, and conclusions made regarding the design, and recommendations for further study. Author

N93-18248# Wright Lab., Wright-Patterson AFB, OH.
ADD-ON DAMPING TREATMENT FOR THE F-15 UPPER-OUTER WING SKIN Final Report, Jan. 1989 - Feb. 1991
VINCENT LEVRAEA, LYNN ROGERS, ARNEL PACIA, and MIKE PARIN 26 Mar. 1992 129 p
(Contract AF PROJ. 2401)
(AD-A258470; WL-TR-92-3069) Avail: CASI HC A07/MF A02

The purpose of this investigation was to design, fabricate, and verify candidate add-on damping treatments for the F-15 upper-outer wing skin. The F-15 upper-outer wing skin has experienced high cycle fatigue cracks caused by separated flow on the upper wing surface. The separated flow results during high load factor maneuvers, and in turn induces large vibratory loads on the upper wing skin and associated substructure. The capability of the F-15 to sustain these maneuvers allows the excitation to

occur for sufficiently long periods of time to result in damage. Damage accumulates due to the resonant vibration of local skin/stiffener modes. The cracks initiate at the fastener holes adjacent to the integrally machined 'T' stiffeners and tend to propagate parallel to the stiffeners. Two damping treatments resulted from the investigation and were recommended for F-15 fleet retrofit. One was an external constrained-layer treatment and the other was an internal 'stand-off' treatment. Laboratory vibration, corrosion, and thermal aging tests were conducted as part of the development of the add-on damping treatments. Estimates of the life extension factors for the external and internal damping treatments were 5 and 34 respectively. GRA

N93-18257# Aeronautical Research Labs., Melbourne (Australia).
DAMAGE TOLERANCE ASSESSMENT OF BORON/EPOXY REPAIRS TO FUSELAGE LAP JOINTS
D. REES, L. MOLENT, and R. JONES Aug. 1992 27 p
(AD-A258383; ARL-STRUC-R-449; DODA-AR-007-103) Avail: CASI HC A03/MF A01

This report describes an experimental program into the damage tolerance of boron/epoxy repairs to multi-site damage in a typical aircraft fuselage lap joint. Repaired lap joint specimens containing adhesive disbonds and impact damage were evaluated using both fatigue and static tension tests. It was demonstrated that such damage had no significant effect on the performance of the repairs. GRA

N93-18304# Naval Postgraduate School, Monterey, CA.
RPH PRELIMINARY DESIGN, TREND ANALYSIS AND INITIAL ANALYSIS OF THE NPS HUMMINGBIRD M.S. Thesis
JAMES L. VANDIVER 24 Sep. 1992 104 p
(AD-A257854) Avail: CASI HC A06/MF A02

The Department of Aeronautics and Astronautics at the Naval Postgraduate School (NPS) is expanding its helicopter research capabilities in order to facilitate present and future research demands. The rapidly changing needs have already outpaced available assets. Therefore, it's necessary to design and develop a new remotely piloted helicopter (RPH) that would meet present needs, NOTAR and HHC, and be flexible enough to meet future needs. The research efforts encompassed by this thesis are defining the present needs, investigating what type/size of RPH would fulfill these needs, procuring this asset, and analyzing its capabilities. Based on a defined payload, helicopter trends are analyzed to determine an estimate of the overall RPH size (gross weight) and engine size required. A preliminary design process validates these figures. Choosing to procure an RPH instead of building one, a detailed performance analysis is conducted on the main rotor system. This analysis includes blade vibration analysis, retreating blade stall analysis, and power required analysis. Modification of the RPH's main rotor hub, drive train, and landing gear are studied and recommendations presented. This research effort is a continuation of a long-term program to provide NPS with robust assets to support present and future rotorcraft research efforts. GRA

N93-18333*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRADE-OFFS ARISING FROM MIXTURE OF COLOR CUEING AND MONOCULAR, BINOPTIC, AND STEREOSCOPIC CUEING INFORMATION FOR SIMULATED ROTORCRAFT FLIGHT
RUSSELL V. PARRISH and STEVEN P. WILLIAMS Feb. 1993 81 p
(Contract DA PROJ. 1L1-61102-AH-45; RTOP 505-64-13-32)
(NASA-TP-3268; L-17085; NAS 1.60:3268; CECOM-TR-92-B-014) Avail: CASI HC A05/MF A01

To provide stereopsis, binocular helmet-mounted display (HMD) systems must trade some of the total field of view available from their two monocular fields to obtain a partial overlap region. The visual field then provides a mixture of cues, with monocular regions on both peripheries and a binoptic (the same image in both eyes) region or, if lateral disparity is introduced to produce two images, a stereoscopic region in the overlapped center. This paper reports on in-simulator assessment of the trade-offs arising from the mixture of color cueing and monocular, binoptic, and stereoscopic cueing information in peripheral monitoring displays as utilized in HMD systems. The accompanying effect of stereoscopic cueing in the tracking information in the central region of the display is also assessed. The pilot's task for the study was to fly at a prescribed height above an undulating pathway in the sky while monitoring a dynamic bar chart displayed in the periphery of their field of view. Control of the simulated rotorcraft was limited to the longitudinal and vertical degrees of freedom to ensure the lateral separation of the viewing conditions of the concurrent tasks. Author

N93-18339# Naval Postgraduate School, Monterey, CA.
AN INVESTIGATION OF A PROTOTYPE OASYS EFFECTIVENESS IN MANEUVERING FLIGHT M.S. Thesis
CHRISTOPHER C. SULLIVAN Sep. 1992 156 p
(AD-A257901) Avail: CASI HC A08/MF A02

An analysis of the current Northrop helicopter obstacle avoidance system (OASYS) prototype with a fixed forward mounting, 25 x 50 degree field of view, 860 nanometer wavelength LADAR, was conducted to determine system effectiveness during simulated aircraft level accelerations ranging from 0 to 100 knots, and at acceleration rates of from 0 to 2.9 meters/sec(exp 2). Computer simulation flights were conducted using flight parameter data recorded at the Army Aero-flight-dynamics Directorate Crew Station Research and Development Facility's (CSRDF) advanced concepts flight simulator. A multiple-program computer simulation was used to model the helicopter and sensor dynamics over a tactical data base of numerous obstacles consisting of trees, wires, and poles; the resulting window of safety (WOS) displays were analyzed by comparing each acceleration maneuver with a control maneuver in which the sensor was horizon stabilized. A mathematical model of the flight maneuvers for which the OASYS prototype operated effectively was then determined based on the results of these simulations. The limits of this analytical flight envelope were then verified experimentally via a series of computer simulations using generalized maneuvers conducted over a standardized obstacle data base. GRA

N93-18349*# Notre Dame Univ., IN. Dept. of Aerospace and Mechanical Engineering.
THE S.T.O.R.M. (TM): AIR TRANSPORT SYSTEM DESIGN SIMULATION Final Design Proposal
May 1992 115 p Sponsored in cooperation with Boeing Commercial Airplane Co.
(Contract NASW-4435)
(NASA-CR-192070; NAS 1.26:192070) Avail: CASI HC A06/MF A02

The members of Team Asylum have proposed a helicopter design concept, called the S.T.o.R.M., in order to meet the market demands for an aircraft to perform overnight package delivery services in Aeroworld. The helicopter concept was chosen over a fixed wing aircraft design to fulfill the mission requirements for a variety of reasons, all of which will be discussed later. However, many critical design areas needed to be investigated as part of the helicopter concept's selection. One of the most significant design factors was the weight of the aircraft. This determined the selection of the propulsion system necessary to get the S.T.o.R.M. off the ground, and maintain flight once airborne. Another significant factor that went hand in hand with the motor selection was the choice of the main rotor. Since the main rotor is the primary source of lift for the helicopter, its proper selection became increasingly important. Author

N93-18350*# Notre Dame Univ., IN. Dept. of Aerospace and Mechanical Engineering.
JEFF: AIR TRANSPORT SYSTEM DESIGN SIMULATION Final Design Proposal
May 1992 116 p Sponsored in cooperation with Boeing Commercial Airplane Co.
(Contract NASW-4435)
(NASA-CR-192069; NAS 1.26:192069) Avail: CASI HC A06/MF A02

Jeff is a remotely piloted vehicle designed by the Blue Team, a division of AE441, Inc., to fulfill the mission proposed by G-Dome Enterprises: to build a cost efficient aircraft to service Aeroworld with overnight cargo delivery. The design of Jeff was most significantly influenced by the need to minimize costs. This objective was pursued by building fewer large planes as opposed to many small planes. Thus, by building an aircraft with a large payload capacity, G-Dome Enterprises will be able to minimize the large costs and the large number of cycles that are associated with a large fleet. Another factor which had a significant influence on our design was the constraint that our design had to fit into a 2'x2'x5' storage container. This constraint meant that unless we wanted to build foldable wings that Jeff's span would be limited to 10 feet. Since this was not enough lifting surface to suit our needs a canard configuration was chosen to get the needed lifting surface and avoid the structural dilemma of foldable wings. The aircraft is constructed mainly of balsa, with spruce wing and canard spars and a monokote covering. It was designed to support a maximum payload weight of 35 oz. (total aircraft weight of 108 oz.) and withstand a maximum load factor of 2.5. I.I.C.

N93-18386*# Notre Dame Univ., IN. Dept. of Aerospace and Mechanical Engineering.
THE F-92 RELIANT: AIR TRANSPORT SYSTEM DESIGN SIMULATION Final Design Proposal
May 1992 175 p Sponsored in cooperation with Boeing Commercial Airplane Co.
(Contract NASW-4435)
(NASA-CR-192050; NAS 1.26:192050) Avail: CASI HC A08/MF A02

The design proposal of a semester long design project by group 'F' for AE 441 is addressed. In formulating this design, the driving philosophy was not just to fulfill the mission requirements (discussed in chapter two), but to do so in a creative manner - this explains the unconventional aircraft design, named the F-92 RELIANT. Although unconventional, and perhaps more expensive to produce, the design has distinct advantages which could only be attained through such a creative design. Major components of the F-92 Reliant include: (1) unobstructed cargo bay, 1024 cu. in. capability; (2) loading ramp; (3) dual wing configuration; and (4) polyhedral wing configuration. These design components either originated or evolved to create an aircraft that would most effectively meet the goals of cargo transportation in AeroWorld at minimum cost. Author

N93-18451# Naval Postgraduate School, Monterey, CA.
STUDY OF STATISTICAL VARIATIONS OF LOAD SPECTRA AND MATERIAL PROPERTIES ON AIRCRAFT FATIGUE LIFE M.S. Thesis
RICHARD W. WALTER, II Sep. 1992 84 p
(AD-A257961) Avail: CASI HC A05/MF A01

NAVAIR utilizes the fatigue spectrum of an existing Navy aircraft to set the structural design requirements for a new Navy aircraft. The current design requirement is for the new aircraft to withstand a fatigue spectrum at least as severe as the spectrum experienced by 99.73 percent (3 standard deviations) of the aircraft from which the design requirement originated. Two years of A-6 data were used in the study, which contained the number of g exceedences at the four g, five g, six g, and seven g levels. Trade off studies were completed to analytically examine the variation in the fatigue life of an aircraft while varying the reference stress at the notch of a crack, re-ordering of the load sequences within the spectrum, varying the 3 sigma design requirement, and changing the material properties of the metal. The results indicated that NAVAIR's current requirement for a new aircraft to withstand a three sigma spectrum may be too severe. This conclusion is only valid for a three sigma spectrum based on the A-6 load history. GRA

N93-18507# Sheffield Univ. (England). Dept. of Control Engineering.
IDENTIFICATION OF SYSTEM DYNAMICS OF A HIGH INCIDENCE RESEARCH MODEL
G. N. JONES and S. A. BILLINGS 1 Oct. 1990 13 p
(RR-407; ETN-92-92766) Avail: CASI HC A03/MF A01

The application of orthogonal nonlinear multivariable identification techniques to model the flight dynamics of a high incidence research model is presented. The system model derived is then shown to be a valid representation of the true system dynamics. The aim of the work is to demonstrate the suitability of the nonlinear identification techniques developed to fulfill the modeling requirements of a research program. The aircraft model and data collection are described. The identification procedures applied, the model validation tests, and the results of the parameter estimation algorithms are presented. The model is shown to be a valid representation of the real system, for both the data used in the identification and for an extended data set, by application of correlation tests and the examination of predicted behavior. ESA

N93-18616*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
OPERATIONAL AND RESEARCH ASPECTS OF A RADIO-CONTROLLED MODEL FLIGHT TEST PROGRAM
GERALD D. BUDD, RONALD L. GILMAN (PRC Kentron, Inc., Edwards, CA.), and DAVID EICHSTEDT (PRC Kentron, Inc., Edwards, CA.) Jan. 1993 18 p Presented at the 31st Aerospace Sciences Meeting, Reno, NV, 11-14 Jan. 1993
(Contract RTOP 505-68-40)
(NASA-TM-104266; H-1881; NAS 1.15:104266; AIAA PAPER 93-0625) Avail: CASI HC A03/MF A01

The operational and research aspects of a subscale, radio-controlled model flight test program are presented. By using low-cost free-flying models, an approach was developed for obtaining research-quality vehicle performance and aerodynamic information. The advantages and limitations learned by applying this approach to a specific flight test program are described. The research quality of the data acquired shows that model flight testing is practical for obtaining consistent and repeatable flight data. Author

N93-18783*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.
NUMERICAL INVESTIGATION OF PERFORMANCE DEGRADATION OF WINGS AND ROTORS DUE TO ICING Progress Report, 1 Jan. - 30 Jun. 1991
LAKSHMI N. SANKAR and OH J. KWON 1991 14 p
(Contract NAG3-768)
(NASA-CR-192233; NAS 1.26:192233) Avail: CASI HC A03/MF A01

During the past five years, under the support of the NASA Lewis Research Center, a research program related to aircraft and rotorcraft icing has been underway at Georgia Institute of Technology. The objectives of this effort are: (1) develop solution techniques capable of computing 3-D unsteady viscous flow past wing-alone and rotor configurations subjected to icing; and (2) assess the performance degradation in the aerodynamic characteristics of these configurations due to icing. Work carried out during the reporting period 1 Jan. - 30 Jun. 1991 is summarized. Author

N93-18895# Aeronautical Systems Div., Wright-Patterson AFB, OH.
ADVERSE WEATHER TEST SITE SELECTION STUDY Final Report, 1 Jun. 1991 - 31 May 1992
STEVEN R. CHRISTY, RONALD L. COMOGLIO, ROBERT G. HAUSER, and RANDY J. LEFEVRE Jul. 1992 94 p
(AD-A259012; ASC-TR-92-5012) Avail: CASI HC A05/MF A01

This report details the percent frequency of occurrence of the adverse weather testing criteria (as outlined in AFFTC-TIH-88-004) for five airfields: Keflavik, Iceland; Goose Bay, Canada; Bodo, Norway; Volk Field, WI; and Dover AFB, DE. The data assists selection of a single location best suited, climatologically, to perform flight testing. Criteria tested and weather conditions evaluated include artificial and natural in-flight icing and rain; wet, slushy, and icy runway/taxiway performance and handling qualities; freezing rain exposure; engine water ingestion on the ground and

in-flight; evaluation of instrument flight rules (IFR) capability; evaluation of the effects of corrosive atmospheric pollutants; and turbulent flight evaluation. Numerous tables and graphs are used to demonstrate the percent frequency differences of the adverse weather conditions between the five locations. GRA

N93-18896# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
AN EXPERIMENTAL INVESTIGATION OF A FINITE CIRCULATION CONTROL WING M.S. Thesis
JOHN M. TALLAROVIC Dec. 1992 76 p
(AD-A259044; AFIT/GAE/ENY/92D-22) Avail: CASI HC A05/MF A01

This wind tunnel investigation examined the lift, drag, and pitching moment of a 20 percent thick, 8.5 percent camber, partial elliptical cross-section, single blowing slot, rectangular, circulation control wing. The aspect ratios tested were 3.71 and 3.99. Variables included three differently shaped trailing edge Coanda surfaces and steady blowing and pulsed blowing. The test Reynolds number, based on the chord was 500,000. The-angle of attack was varied from minus 6 degrees to the inception of stall. The maximum lift coefficient measured was 3.17 with an equivalent drag coefficient of 1.85. Results also show a limit to increasing lift by increasing the blowing. Additionally, a 90 degree Coanda surface had equal lift performance and better drag performance than a 180 degree Coanda surface. GRA

N93-18981# General Accounting Office, Washington, DC. National Security and International Affairs Div.
NATIONAL AERO-SPACE PLANE: RESTRUCTURING FUTURE RESEARCH AND DEVELOPMENT EFFORTS
Dec. 1992 57 p
(AD-A258799; GAO/NSIAD-93-71) Avail: CASI HC A04/MF A01

U.S. efforts to develop and demonstrate an aerospace plane that could achieve low earth orbit using a single stage are focused in the National Aero-Space Plane (NASP) Program. However, the program faces an uncertain future as it competes with other programs for limited federal funding at the same time its costs have escalated and its technologies remain to be developed within an ambitious schedule. Because of these and other concerns, three congressional committees asked GAO to examine various aspects of the NASP Program. This report discusses: (1) the status of the program's technology development; (2) changes in the program's projected cost and schedule; (3) the requirements for and the potential mission applications of future operational NASP-derived vehicles and efforts to spin off NASP-developed technology; and(4) issues to be decided in reassessing the direction of the program. GRA

N93-18999# Detroit Univ., MI. Dept. of Mechanical Engineering.
AIRCRAFT TRAJECTORY TRACKING AND PREDICTION Final Report, Sep. 1991 - Sep. 1992
LUIS C. CATTANI, PAUL J. EAGLE, ZHUD LIN, and XIN LIU Oct. 1992 51 p
(Contract DAAA21-91-C-0085)
(AD-A259039) Avail: CASI HC A04/MF A01

Regression modeling of trajectory measurement data was examined as a means for improving the performance of aircraft trajectory tracking and prediction. Regression models were used for adaptively removing measurement noise from trajectory observations and extrapolating trajectory measurements. A comparative study was done between three models of aircraft dynamics used in an extended Kalman filter: a strictly translational model, an attitude/translation model, and an attitude/translation model that uses vehicle specific inertial characteristics. Adaptive regression models were used for measurement accuracy enhancement. Comparisons were also made between errors resulting from position and attitude predictions using Runge-Kutta integration and extrapolated regression models. GRA

N93-19004# Technische Univ., Delft (Netherlands).
AIRCRAFT PERFORMANCE IN PRACTICE [VLIEGTUIGPRESTATIES IN DE PRAKTIJK]
H. WICKARDT *In its* Professor Wittenberg: His Speciality and Versatility p 29-41 1991 In DUTCH
Copyright Avail: CASI HC A03/MF A01

The different activities within the Engineering Directorate of Fokker in the field of aircraft performance are summarized. The predesign division performs calculations for design studies, including alternatives of existing production programs as well as new projects. The division's operations provide customers with aircraft performance information, so that the customer may use their aircraft in a safe and economical manner. The Airline Analysis Division (of the Marketing and Sales Directorate) provides information concerning the performance of Fokker aircraft and their competitors'. ESA

N93-19005# KLM Helikopters B.V., Amsterdam (Netherlands).
HELICOPTERS IN ACTION [HELIKOPTERS IN AKTIE]
H. W. C. L. SCHOEVERS *In* Technische Univ., Professor Wittenberg: His Specialty and Versatility p 43-57 1991 In DUTCH
Copyright Avail: CASI HC A03/MF A01

The use of helicopters is outlined. The individual performances of helicopters are unique, but the application domain is relatively small scale, with the exception of military and offshore applications. The offshore applications are discussed. These applications include the following: air traffic control, processing of flight data, takeoff and landing, and the requirements for offshore transport. ESA

N93-19029 Missouri Univ., Rolla.
AIRCRAFT LANDING GEAR SHIMMY Ph.D. Thesis
JEFFREY ALLEN BAUMANN 1992 133 p
Avail: Univ. Microfilms Order No. DA9239687

In the landing gear of taxiing aircraft, shimmy is a condition of self-excited oscillation driven by the interaction between the tires and the ground. In extreme cases, shimmy can cause severe damage to landing gear hardware or even loss of the aircraft. In less extreme cases, shimmy can be little more than an annoyance. However, it does affect customer satisfaction and can cause added maintenance expense. Thus, the ability to predict and to control shimmy is important to the landing gear designer. This work discusses two analytical landing gear shimmy models. The first model, featuring an improved torsional model, is nonlinear. Its results can be integrated numerically to simulate the response of the landing gear to a specified initial disturbance. The second model is linear, combining a finite element model of the landing gear structure with a rigid or a point-contact tire model. This model can be analyzed with standard eigenvalue/eigenvector techniques to determine stability. A test case run with two models shows good correlation and illustrates the effects of changes to various parameters. Dissert. Abstr.

N93-19034 Illinois Univ., Chicago.
FLEXIBLE ROTORCRAFT SYSTEM DYNAMICS WITH TIME-VARIANT CONTACT CONDITIONS Ph.D. Thesis
MINGJUN XIE 1992 175 p
Avail: Univ. Microfilms Order No. DA9238366

In this thesis research an effective mathematical algorithm is developed for the dynamic analysis and simulation of flexible rotorcraft systems. A recursive matrix formulation of the equations of motion in a minimum dimension form is presented. The equations are developed for general purposes analysis and include the effects of high temperature, creep, thermal shock, elastic-plastic deformation, geometrical nonlinearities and material nonlinearities. The method used employs Kane's equations combined with the finite element method and the principle of continuum mechanics. Adjustable and time variant boundary conditions are studied for different constrained flexible systems. These include the mesh of gears, train moving on the rail and movable support. The switching of the constraints in the case of gear meshes is done by changing the nodes at contact. This is achieved by a mapping technique between the discretized finite element bodies. In addition, the rate

of change of modal shapes due to the time variant boundary conditions is also considered. For validation of the results, the dynamics of a gear tooth is modeled using a modified Timoshenko beam where the acting position, direction and magnitude of the external force assumed time variant are presented. The meshing tooth is considered as a cantilever beam where the inertia forces due to the large rotation of the tooth base, as well as the external equivalent axial force and moment are included in the equations of motion. Based on the concept of time variant boundary conditions, minimization and control of vibration in elastic shafts in the dynamics of rotorcraft systems are also given. Numerical simulations supporting the broad developments of this thesis research are presented. Dissert. Abstr.

N93-19089# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
NOZZLE/COWL OPTIMIZATION FOR A HYPERSONIC VEHICLE ON A TYPICAL TRAJECTORY M.S. Thesis
MICHAEL J. BONAPARTE Dec. 1992 81 p
(AD-A258827; AFIT/GAE/ENY/92D-10) Avail: CASI HC A05/MF A01

An investigation of the effects of simultaneous variation of the nozzle attachment and cowl deflection angle on the performance of a two-dimensional nozzle used on a hypersonic vehicle such as the National Aero-Space Plane (NASP) was performed using a two parameter optimization procedure. Total thrust optimization was accomplished using a Flux-Difference-Split (FDS) code, a Ramjet Performance Analysis program, and an oblique shock wave solver program, at sixteen points on a 1000 psf dynamic pressure trajectory for Mach numbers from 10.0 to 25.0. A single parameter optimization of the total thrust using a variable nozzle attachment angle was accomplished first to establish a reference frame. Effects of a deflected cowl on the nozzle flow field were explored. The optimum nozzle attachment and cowl deflection angle maximized the total thrust by increasing nozzle wall pressure without an excessive increase in pressure drag. The total thrust found by the two parameter optimization was increased at every point on the trajectory over the total thrust obtained from the single parameter optimization. This study shows that the cowl deflection angle starts negative, increasing from -0.493 degrees at Mach 10 to 3.01 degrees at Mach 25. GRA

N93-19322# *National Aerospace Lab., Tokyo (Japan).*
ON THE ROLES OF WIND TUNNEL TESTING AND COMPUTATIONAL FLUID DYNAMICS IN THE AIRCRAFT DEVELOPMENT [KOUKUUKI KAIHATSU NI OKERU FUUDOU SHIKEN TO CFD]
SUSUMU TAKANASHI *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 313-318 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

In this paper, the roles of wind tunnel testing and Computational Fluid Dynamics (CFD) in the aircraft development is briefly described. The stress is put on the importance of CFD as an aerodynamic design tool to drastically reduce both cost and period of development. Prior to the application of CFD to practical design problems, the existing CFD codes must be verified with the reliable experimental data. A demonstrative example of CFD validation is presented to show the state of the arts of CFD by comparing the Navier-Stokes simulation results with the transonic wind tunnel test data for a NACA0012 airfoil at several angles of attack. The importance of application of CFD to inverse design problem is also discussed. Author (NASDA)

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

A93-17574
TRENDS IN ADVANCED AVIONICS
JIM CURRAN Ames, IA Iowa State University Press 1992 199 p. refs
(ISBN 0-8138-0749-2) Copyright

The hallmarks of next generation avionics, human-centered automation, integrated modular systems, and improved overall performance are explored. Particular attention is given to the supporting technological advances, and the limitations imposed by the real-world business, economic, political, and human factors constraints. The book describes the trends in avionics systems, in particular, converging and consolidating avionics functions in highly integrated systems. Emphasis is placed on major trends in the areas of communication, navigation, flight control, and integrated avionics management systems, advances in the underlying technology that make these trends possible, and current aircraft programs. O.G.

A93-17864* *National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.*
LIDAR WINDSHEAR DETECTION FOR COMMERCIAL AIRCRAFT
RUSSELL TARG (Lockheed Missiles & Space Co., Inc., Palo Alto, CA) and ROLAND L. BOWLES (NASA, Langley Research Center, Hampton, VA) *In* Laser radar VI; Proceedings of the Meeting, Los Angeles, CA, Jan. 23-25, 1991 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 130-138. refs
Copyright

As part of the NASA/FAA National Integrated Windshear Program, a measurable windshear hazard index that can be remotely sensed from an aircraft is presented. This will provide a pilot information about the wind conditions he will experience at some later time if he continues along the present flight path. The technology analysis and end-to-end performance simulation, which measured S/N and resulting wind velocity errors for competing lidar systems, demonstrated that a Ho:YAG lidar at a wavelength of 2.1 microns and a CO2 lidar at 10.6 microns can give the pilot data about the line-of-sight component of a windshear threat in an area extending from his present position to two to four km in front of the aircraft. R.E.P.

A93-18364
ASSESSMENT OF FLIGHT DATA IN REAL TIME [OTSENKA POLETNOI INFORMATSII V REAL'NOM MASSHTABE VREMENI]
R. A. KOPYTOV, V. L. RASTRIGIN, and E. A. SHUL'KIN *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 55-59. In Russian. refs
Copyright

A nontraditional method is proposed for obtaining robust estimates of the diagnosed parameters during the continuous monitoring of the Il-86 aircraft engine. The estimates are made in real time on the basis of flight data, which reduces the required computational resources. The statistical properties of the estimates proposed here and their modifications are examined. V.L.

A93-18532
MODEL OF A MAP INDICATOR [MODEL WSKAZNIKA MAPOWEGO]
M. WACHOWICZ (Inst. Lotnictwa, Warsaw, Poland) Instytut Lotnictwa, Prace (ISSN 0509-6669) no. 129-130 1992 p. 62-98. In Polish. refs

The proposed solution of a map indicator model concerns the organization system of the digital map data base, map

transformation system of the digital map data base, map transformation on the monitor screen, working modes of the indicator and its graphic form. Software of the prepared project of the map indicator model has been made for simulating tests in the Aeronautical Equipment and Satellitar Systems Department of the Aviation Institute where a laboratory for modelling and ergonomic tests of aeronautical navigation systems has been established. Tests of the model of a map indicator have been performed on a simplified flight simulator concerning ergonomic possibility of picture generation applying the available computer equipment of the family IBM PC. Test results permit to formulate optimum criteria of the indicator design and to design the structure of the digital data base describing the map for aeronautical applications. Author

A93-19801* National Aeronautics and Space Administration, Washington, DC.

DIGITAL AVIONICS SYSTEMS - PRINCIPLES AND PRACTICES (2ND REVISED AND ENLARGED EDITION)

CARY R. SPITZER (NASA, Washington) New York McGraw-Hill, Inc. 1993 291 p. refs

(ISBN 0-07-060333-2) Copyright

The state of the art in digital avionics systems is surveyed. The general topics addressed include: establishing avionics system requirements; avionics systems essentials in data bases, crew interfaces, and power; fault tolerance, maintainability, and reliability; architectures; packaging and fitting the system into the aircraft; hardware assessment and validation; software design, assessment, and validation; determining the costs of avionics. C.D.

A93-20851

SUPERRESOLUTION RADAR IMAGING WITH LINEAR PREDICTION DATA EXTRAPOLATION

ZHAODA ZHU, ZHENRU YE, and XIAOQING WU (Nanjing Aeronautical Inst., China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956) vol. 24, no. 6 Dec. 1992 p. 645-650. In Chinese. refs

The superresolution imaging possibilities of the linear prediction data extrapolation/discrete Fourier transform (LPDEDFT) method are presently investigated with a view to overcoming limitations associated with the conventional FFT range-Doppler processing method and improving on its levels of resolution. LPDEDFT superresolution imaging extrapolates observed data beyomd the observation window by means of linear prediction. It is concluded on the basis of microwave anechoic chamber model test results that performance superior to that of conventional Fourier methods is obtainable by this means. O.C.

A93-20852

RESEARCH ON ISAR MOTION COMPENSATION AND IMAGING BY MODELING ELECTROMAGNETIC DATA

JIANJIANG ZHU, ZHAODA ZHU, and XIAOQING WU (Nanjing *Aeronautical Inst., China) Nanjing Aeronautical Institute, Journal* (ISSN 1000-1956) vol. 24, no. 6 Dec. 1992 p. 651-658. In Chinese. refs

This paper studies the electromagnetic simulation of a moving target by means of the panel method. The integration equation of the far-zone electromagnetic scattering of a target is simplified by breaking the target shape up into panels, after the CAD of the target configuration is finished; the scattering field is then obtained for a stationary target. Taking account for the moving orbit of the target, the modeling electromagnetic data of the moving target is established. Using these data, the ISAR motion compensation and imaging of an aircraft, in level flight (with constant speed) and illuminated by an X-band radar, are accomplished by means of the maximum likelihood method. Author

A93-20857

THE ISAR IMAGE-FORMATION RESULTS OF BOEING-727

ZHISHUN SHE and ZHAODA ZHU (Nanjing Aeronautical Inst., China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956) vol. 24, no. 6 Dec. 1992 p. 704-709. In Chinese. refs

Live data from a B727 airliner are used in the present investigation of inverse-SAR (ISAR) information processing for both image formation and motion compensation. Several motion-compensation schemes are formulated and compared; image-formation is conducted by FFT range-Doppler processing and superresolution processing. Attention is given to a B727 airliner's reconstructed ISAR images, which demonstrate the accuracy of these motion-compensation approaches. O.C.

A93-21104*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

UNSTEADY LOADS MEASUREMENTS IN A GENERIC HIGH SPEED ENGINE MODEL BY MEANS OF RECESSED TRANSDUCERS

TONY L. PARROTT (NASA, Langley Research Center, Hampton, VA) and MICHAEL G. JONES (Lockheed Engineering and Sciences Co., Hampton, VA) Jan. 1993 25 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(AIAA PAPER 93-0287) Copyright

Results are presented from measurements of unsteady loads during performance tests of a generic high-speed engine model, which were made using high-frequency pressure gages installed in existing calorimeter ports of the engine model and recessed into the interior wall surface in order to reduce thermal flux to the gage diaphragm. In was found that the boundary layer pressure spectra at the model wall start to deviate from their flat plate counterpart at a short distance into the model inlet, which suggests the contributions to the spectra from the shock/boundary layer interaction. It was also found that significant levels of combustion noise propagate up through the subsonic portion of the boundary layer well into the inlet region. At the condition of an unstart, the combustion noise apparently couples with the acoustic modes of the model to cause acoustic 'hot spots' well upstream of the combustor. I.S.

A93-21146* National Aeronautics and Space Administration, Washington, DC.

GUIDANCE ACCURACY CONSIDERATIONS FOR REALTIME GPS INTERFEROMETRY

MICHAEL S. BRAASCH and FRANK VAN GRAAS (Ohio Univ., Athens) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 373-386. Research supported by FAA refs

(Contract NGR-36-009-017; DTRS-57-87-C-00006)

During April and May of 1991, the Avionics Engineering Center at Ohio University completed the first set of realtime flight tests of a GPS interferometric attitude and heading determination system. This technique has myriad applications for aircraft and spacecraft guidance and control. However, before these applications can be further developed, a number of guidance accuracy issues must be considered. Among these are: signal derogation due to multipath *and shadowing, effects of structural flexures, and system* robustness during loss of phase lock. This paper addresses these issues with special emphasis on the information content of the GPS signal, and characterization and mitigation of multipath encountered while in flight. Author

A93-21193

FALSE ALARM PROBABILITY DETERMINATION FOR THE HONEYWELL HEXAD FAULT-TOLERANT INS

DANIEL P. JOHNSON (Honeywell Systems and Research Center, Minneapolis, MN) *In* Institute of Navigation, National Technical Meeting, San Diego, CA, Jan. 27-29, 1992, Proceedings Washington Institute of Navigation 1992 p. 245-252. refs

The present Fault-Tolerant ADIRU uses six skew-mounted gyros and accelerometers to achieve fail-operational/fail-operational/fail-safe redundancy. The algorithm for fault detection tests whether a 3D parity vector has exceeded a preset threshold. False alarm probability calculations for such a system involve the evolution of a 3D stationary stochastic process. This paper presents the derivation of simple bounding formulas for the false alarm probability based on the discrete time version

of level-crossing theory for multidimensional random processes, resulting in the setting of thresholds for the Honeywell ADIRU at 10 exp -6 probability of false alarm/hour operation. Author

A93-21966
A HIGH RESOLUTION AIRBORNE MULTISENSOR SYSTEM
S. PRUTZER, D. G. BIRON, and T. M. QUIST (MIT, Lexington, MA) *In* Sensors and sensor integration; Proceedings of the Meeting, Orlando, FL, Apr. 4, 1991 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 46-61. Research sponsored by DARPA and USAF refs
Copyright

An aircraft based multisensor system consisting of forward-looking and down-looking sensor suites has been developed. Sensors which have been evaluated in this system include CO2 and near IR laser radars, long-wave passive IR extending to 12 microns and an 85.5 GHz millimeter wave (MMW) radar. Sensor descriptions are presented along with example imagery. The goals of this continual effort are deeper understanding of the data characteristics, including realistic phenomenology, and the delivery of co-registered, multidimensional sensor data for the development of detection and classification algorithms. Author

A93-22111* National Aeronautics and Space Administration, Washington, DC.
AN EXPERIMENTAL COCKPIT DISPLAY FOR TDWR WIND SHEAR ALERTS
STEVEN D. CAMPBELL, PETER M. DALY, and ROBERT J. DEMILLO (MIT, Lexington, MA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 39-44. Research sponsored by NASA refs
(Contract F19628-90-C-0002)
Copyright

The first successful ground-to-air data link and cockpit display of terminal Doppler weather radar (TDWR) wind shear warnings in real-time are reported. During the summer of 1990, wind shear warnings generated by the TDWR testbed radar at Orlando, Florida, were transmitted in real-time to a research aircraft performing microburst penetrations. Automatic delivery of TDWR wind shear warnings potentially result in decreased controller workload and improved pilot information. Pilot responses indicate that the information provided by the cockpit displays was useful in visualizing the location of wind shear hazards. The graphical display of microburst hazards provided better information than that currently provided by ATC verbal messages and pilot reports. This information was useful in assessing the microburst hazard, deciding whether to continue the approach, and planning escape maneuvers. P.D.

A93-22851* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
VISION-BASED RECURSIVE ESTIMATION OF ROTORCRAFT OBSTACLE LOCATIONS
D. J. LEBLANC and N. H. MCCLAMROCH (Michigan Univ., Ann Arbor) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 937-941. refs
(Contract NCC2-573)
Copyright

The authors address vision-based passive ranging during nap-of-the-earth (NOE) rotorcraft flight. They consider the problem of estimating the relative location of identifiable features on nearby obstacles, assuming a sequence of noisy camera images and imperfect measurements of the camera's translation and rotation. An iterated extended Kalman filter is used to provide recursive range estimation. The correspondence problem is simplified by predicting and tracking each feature's image within the Kalman filter framework. Simulation results are presented which show convergent estimates and generally successful feature point tracking. Estimation performance degrades for features near the optical axis and for accelerating motions. Image tracking is also sensitive to angular rate. I.E.

N93-16693*# Boeing Commercial Airplane Co., Seattle, WA.
DEFINITION OF THE 2005 FLIGHT DECK ENVIRONMENT Final Report
K. W. ALTER and D. M. REGAL Washington Dec. 1992 108 p
(Contract NAS1-18027; RTOP 505-64-13-23)
(NASA-CR-4479; NAS 1.26:4479) Avail: CASI HC A06/MF A02

A detailed description of the functional requirements necessary to complete any normal commercial flight or to handle any plausible abnormal situation is provided. This analysis is enhanced with an examination of possible future developments and constraints in the areas of air traffic organization and flight deck technologies (including new devices and procedures) which may influence the design of 2005 flight decks. This study includes a discussion on the importance of a systematic approach to identifying and solving flight deck information management issues, and a description of how the present work can be utilized as part of this approach. While the intent of this study was to investigate issues surrounding information management in 2005-era supersonic commercial transports, this document may be applicable to any research endeavor related to future flight deck system design in either supersonic or subsonic airplane development. Author

N93-17547# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Avionic System Integration Dept.
TEST AND INTEGRATION CONCEPT FOR COMPLEX HELICOPTER AVIONIC SYSTEMS
HORST GOELZENLEUCHTER and LOTHAR DIETL 1991 8 p Presented at 17th European Rotorcraft Forum, Berlin, Germany, 24-27 Sep. 1991; sponsored by DGLR Previously announced in IAA as A92-56292
(MBB-UD-0605-91-PUB; ETN-92-92581) Avail: CASI HC A02/MF A01

The stages in the development and integration of the TIGER basic avionic system are described. The most important integration tools for avionic integration purposes are described. These include an integrating rig for the installation and operation of the avionic equipment, patch panels which allow an access to all avionic signals, and a test system for complex measurements and tests. Besides the test system, various laboratory test equipment for direct signal stimulation for measurements are used. The tasks of the real time test system used for integration of the TIGER avionic system are described. These include the validation and monitoring of interface data flow, and simulation of environment/equipment data. The test system performance is considered. It is concluded that the test means for the TIGER basic avionic system offer the required flexibility for the integration of the various national versions of this helicopter at the same test rig. The use of an off the shelf test system avoids any development risks of a 'selfmade' solution. ESA

N93-17570# Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany). Helicopter Div.
INTEGRATED HELMET SYSTEM TESTING FOR A NIGHTFLYING HELICOPTER
HANS-DIETER BOEHM and HERBERT SCHREYER 1991 20 p Presented at 17th European Rotorcraft Forum, Berlin, Germany, 24-27 Sep. 1991; sponsored by DGLR Previously announced in IAA as A92-56291
(MBB-UD-0604-91-PUB; ETN-92-92580) Avail: CASI HC A03/MF A01

The requirements for and testing of an Integrated Helmet System (IHS) for helicopter application are presented. An IHS consists of a helmet shell, a Helmet Mounted Sight (HMS), two Image Intensifier Tubes (IIT) and two Cathode Ray Tubes (CRT) with an optical system including combiners to present the images binocular. Additional symbology can be superimposed to the CRT or IIT image. The HMS can steer a sensor platform with a thermal camera or an air to air missile system. The main helicopter requirements on such a system are: human factors; fit of helmet including optimized center of gravity and weight; optimized day, twilight and night optical modules; large exit pupil, good transmission of the optical path and a large adjustment range;

good geometrical resolution/modulation transfer function with a large field of view; high focussing range of the IIT; CRT automatic brightness and contrast control with a good readability in day time; flight symbology presentation for one or two eyes; good static and dynamic HMS accuracy with a large head motion box; NBC (Nuclear, Biological, Chemical) and laser protection compatibility. The results of helicopter flight trials and laboratory tests showed there is no substitute for flight trials to completely understand an IHS for day and night flight capability. The difficult human engineering aspects have to be evaluated with functional IHS models to find the necessary improvements. ESA

N93-18270# Carnegie-Mellon Univ., Pittsburgh, PA. Software Engineering Inst.
JOINT INTEGRATED AVIONICS WORKING GROUP (JIAWG) OBJECT-ORIENTED DOMAIN ANALYSIS METHOD (JODA), VERSION 3.1 Final Report
ROBERT HOLIBAUGH Nov. 1992 100 p
(Contract F19628-90-C-0003)
(AD-A258468; CMU/SEI-92-SR-3) Avail: CASI HC A05/MF A02

The Joint Integrated Avionics Working Group (JIAWG) Reuse Subcommittee has initiatives in several areas to demonstrate that reuse can effectively support the JIAWG programs, and the creation of reusable assets is an essential element of reuse. Domain analysis is the process that identifies what is reusable, how it can be structured, and how it can be used. A method for domain analysis that is based on Coad and Yourdon's Object Oriented Analysis is desribed. This method, the JIAWG Object-Oriented Domain Analysis (JODA), includes several enhancements to the method of Coad and Yourdon and produces a domain model to support asset creation and reuse. GRA

N93-18408*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MANUAL FLYING OF CURVED PRECISION APPROACHES TO LANDING WITH ELECTROMECHANICAL INSTRUMENTATION. A PILOTED SIMULATION STUDY
CHARLES E. KNOX Washington Feb. 1993 41 p
(Contract RTOP 505-64-13-01)
(NASA-TP-3255; L-16964; NAS 1.60:3255) Avail: CASI HC A03/MF A01

A piloted simulation study was conducted to examine the requirements for using electromechanical flight instrumentation to provide situation information and flight guidance for manually controlled flight along curved precision approach paths to a landing. Six pilots were used as test subjects. The data from these tests indicated that flight director guidance is required for the manually controlled flight of a jet transport airplane on curved approach paths. Acceptable path tracking performance was attained with each of the three situation information algorithms tested. Approach paths with both multiple sequential turns and short final path segments were evaluated. Pilot comments indicated that all the approach paths tested could be used in normal airline operations. Author

N93-19023*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STALL DEPARTURE RESISTANCE ENHANCER Patent Application
HOLLY M. ROSS, inventor (to NASA), JOSEPH L. JOHNSON, JR., inventor (to NASA), LONG P. YIP, inventor (to NASA), and H. PAUL STOUGH, III, inventor (to NASA) 4 Jan. 1993 10 p
(NASA-CASE-LAR-14221-1; NAS 1.71:LAR-14221-1; US-PATENT-APPL-SN-000064) Avail: CASI HC A02/MF A01

A stall departure resistance enhancer for an aircraft for controlling flow separation by inducing vortical flow over the upper surface of the wing is described. A flat triangular plate is secured to a leading edge of the wing to reduce drag, and the tip of the triangular plate is sharp and the edges are thin and sharp to induce good vortical flow. The thickness of the plate is minimal, but it is sufficient so that the plate remains rigid for all angles of attack. A tip of the triangular plate protrudes forward from the leading edge of the wing, and the centerline of the triangular plate extending through the tip is aligned in the freestream direction. In a second embodiment, the triangular plate is hingedly secured to the leading edge of the wing, and a stop is provided to limit the hinged movement of the plate at or near the stall angle of attack. NASA

N93-19110*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
FLIGHT AND WIND-TUNNEL CALIBRATIONS OF A FLUSH AIRDATA SENSOR AT HIGH ANGLES OF ATTACK AND SIDESLIP AND AT SUPERSONIC MACH NUMBERS
TIMOTHY R. MOES, STEPHEN A. WHITMORE, and FRANK L. JORDAN, JR. (National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.) Feb. 1993 33 p
Presented at the AIAA/AHS/ASEE Aerospace Design Conference, Irvine, CA, 16-19 Feb. 1993
(Contract RTOP 505-68-30)
(NASA-TM-104265; H-1875; NAS 1.15:104265; AIAA PAPER 93-1017) Copyright Avail: CASI HC A03/MF A01

A nonintrusive airdata-sensing system was calibrated in flight and wind-tunnel experiments to an angle of attack of 70 deg and to angles of sideslip of +/- 15 deg. Flight-calibration data have also been obtained to Mach 1.2. The sensor, known as the flush airdata sensor, was installed on the nosecap of an F-18 aircraft for flight tests and on a full-scale F-18 forebody for wind-tunnel tests. Flight tests occurred at the NASA Dryden Flight Research Facility, Edwards, California, using the F-18 High Alpha Research Vehicle. Wind-tunnel tests were conducted in the 30- by 60-ft wind tunnel at the NASA LaRC, Hampton, Virginia. The sensor consisted of 23 flush-mounted pressure ports arranged in concentric circles and located within 1.75 in. of the tip of the nosecap. An overdetermined mathematical model was used to relate the pressure measurements to the local airdata quantities. The mathematical model was based on potential flow over a sphere and was empirically adjusted based on flight and wind-tunnel data. For quasi-steady maneuvering, the mathematical model worked well throughout the subsonic, transonic, and low supersonic flight regimes. The model also worked well throughout the angles-of-attack and -sideslip regions studied. Author

07

AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and on-board auxiliary power plants for aircraft.

A93-17899
TURBOMACHINE BLADE VIBRATION
J. S. RAO (Indian Inst. of Technology, New Delhi, India) New York John Wiley & Sons, Inc. 1991 456 p. refs
(ISBN 0-470-21764-2) Copyright

A survey of free vibratory behavior of turbine blades, including free standing, packetted, and bladed discs is presented. The analysis is based on continuous and discrete models using energy principles and finite element methods. The book provides a clear understanding of the interference phenomenon in a thin cambered airfoil stage in subsonic flow to determine the nonsteady excitation forces acting on the blades. Particular attention is given to the blade damping phenomenon, the nonlinear damping models which take into account material and friction damping as a function of rotational speed for each mode, resonant response calculation procedures for the steadily running and accelerating blades, and cumulative damage calculations for fatigue life estimation of turbomachine blades. O.G.

A93-18337
PROBABILITY ANALYSIS OF A METHOD FOR DIAGNOSING GAS TURBINE ENGINES ON THE BASIS OF THERMOGASDYNAMIC PARAMETERS [VEROIATNOSTNYI ANALIZ METODIKI DIAGNOSTIROVANIIA GTD PO TERMOGAZODINAMICHESKIM PARAMETRAM]
I. V. IATSKIV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 49-54. In Russian. refs
Copyright
A probability analysis is used to evaluate diagnostic methods for gas turbine engines based on parametric control methods. Particular attention is given to different methods of determining the probability of a false signal. Some particular cases are considered. V.L.

A93-18342
EFFECT OF DESIGN AND SERVICE-RELATED FACTORS ON THE FORMATION OF COMBUSTION RESIDUES IN THE FUEL NOZZLES OF GAS TURBINE ENGINES [O VLIIANII KONSTRUKTIVNYKH I EKSPLUATATSIONNYKH FAKTOROV NA OBRAZOVANIE NAGAROV V TOPLIVNYKH FORSUNKAKH GTD]
V. F. BANBAN and V. IU. KOLOBANOV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 80-82. In Russian. refs
Copyright
An analysis is made of the effect of the design characteristics of fuel nozzles, type of fuel, and operating regimes of the gas turbine engine on changes in the nozzle characteristics resulting from the formation of combustion deposits. Ways of reducing the amount of combustion residues in the fuel nozzles are discussed. V.L.

A93-18356
CALCULATION OF FUEL ECONOMY FOR THE TU-154 AIRCRAFT IN RELATION TO THE WASHING OF THE NK-8-2U ENGINE AT CIVIL AVIATION MAINTENANCE FACILITIES [RASCHET EKONOMII TOPLIVA DLIA SAMOLETA TU-154, SVIAZANNOI S PROMYVKOI DVIGATELIA NK-8-2U V EKSPLUATATSIONNYKH PREDPRIIATIIAKH GRAZHDANSKOI AVIATSII]
V. F. BANBAN, V. IU. KOLOBANOV, N. C. KUZNETSOV, and V. P. LABENDIK *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 20-25. In Russian. refs
Copyright
A method is presented for calculating the fuel economy of the NK-8-2U engine following a maintenance wash designed to restore its performance characteristics. An analysis of the results of the study reported here indicates that the periodic washing of gas turbine engines in the course of their service makes it possible to increase the service life of the engines and partially restore their fuel economy and performance. V.L.

A93-18372
A UNIFIED APPROACH TO THE CONSTRUCTION OF THE THROTTLE CHARACTERISTICS OF POSTREPAIR TURBOJET ENGINES, WITH THE NK8-2U ENGINE USED AS AN EXAMPLE [EDINYI PODKHOD K POSTROENIIU DROSSEL'NYKH KHARAKTERISTIK POSLEREMONTNYKH TRD NA PRIMERE DVIGATELIA NK8-2U]
N. S. KULESHOV, IU. IU. SOPULIS, and S. V. SHUL'ZHIK *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 94-101. In Russian. refs
Copyright
A statistical justification is presented for the use of a combined throttle characteristic when constructing the throttle characteristics of postrepair turbojet engines. The advantages of the combined throttle characteristic for standardizing the process of estimating the parameters of postrepair turbojet engines are demonstrated with particular reference to the NK8-2U engine. V.L.

A93-18778
AERO ENGINE RELIABILITY, INTEGRITY AND SAFETY; PROCEEDINGS OF THE CONFERENCE, BRISTOL, UNITED KINGDOM, OCT. 17, 18, 1991
London Royal Aeronautical Society 1991 136 p.
(ISBN 0-903409-70-4) Copyright
The present conference on aircraft engine safety and reliability discusses the achievement of safety through integrity and reliability, Extended-Range Operations of Twin-Engined Transport Aircraft, the military view of aircraft engine reliability, and service life determination philosophies for fracture-critical parts. Also discussed are aspects of turbine blade design for integrity, engine integrity testing, reliability and safety considerations in engine management systems design, engine health monitoring, the costs and consequences associated with very high reliability, and the use of advanced technology for high reliability as well as high performance. (For individual items see A93-18779 to A93-18790) O.C.

A93-18782
AERO-ENGINE RELIABILITY - A GE VIEW
AMBROSE A. HAUSER and SIDNEY B. ELSTON, III (General Electric Co., Cincinnati, OH) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 4.1-4.14.
Copyright
A development history and reliability-maximizing design method rationale are presented for a major turbofan engine manufacturer's wide-chord composite fan blades, which exemplify this rationale. The wide-chord composite fan blades were initially developed for the GE36 unducted fan demonstrator, and subsequently applied to the GE90 high bypass ratio turbofan. Developmental fatigue and both hardbody and birdstrike impact tests have demonstrated the damage-resistance and durability of these blades. Robotic fabrication techniques are used to produce composite blades with minimum property variations. O.C.

A93-18783
LIFING PHILOSOPHIES FOR AERO ENGINE FRACTURE CRITICAL PARTS
G. F. HARRISON and D. P. SHEPHERD (Royal Aircraft Establishment, Farnborough, United Kingdom) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 5.1-5.14. refs
Copyright
Although safety is the primary aim of any service-life estimation ('lifing') procedure, it is economically and operationally essential to ensure the longest possible service life as well. While under current European lifing regulations specimen fatigue data are used solely at the design stage, and actual service life is declared on the basis of full-scale component rig testing, the U.S. lifing regulations accept laboratory specimen data as sufficient validation of a chosen statistical model. Attention is presently given to safe-predicted total life, data-base lifing, damage tolerance considerations, and developing trends in rotating component lifing. O.C.

A93-18784
ASPECTS OF TURBINE BLADE DESIGN FOR INTEGRITY
S. M. BAGNALL (Rolls-Royce, PLC, Derby, United Kingdom) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 6.1-6.13. refs
Copyright
An account is given of current design approaches for ensuring turbine blade integrity in its prime failure modes of high cycle fatigue, creep, low cycle fatigue, and thermal protection coating failure. Attention is given to changes in design methodology aimed at the achievement of greater integrity in conjunction with increased confidence from design-analysis advancements, as well as to the role played in contemporary practice by design validation methods

employing specimen and component tests. The requirements for materials data bases are evaluated in light of changing design philosophy. O.C.

A93-18785
TESTING FOR INTEGRITY
J. HORSLEY (Rolls-Royce, PLC, Derby, United Kingdom) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 7.1-7.13. Previously announced in STAR as N93-11024
Copyright

Principal tests involved and techniques and facilities used to carry out tests of stresses and strains induced in gas turbine engine components during service are described. Focus is on civil engines. Three categories of tests are outlined: engine tests, component tests, and specimen tests. Lubrication and transmission testing is also considered. Author

A93-18786
RELIABILITY AND SAFETY CONSIDERATIONS IN ENGINE MANAGEMENT SYSTEMS DESIGN
P. A. DOOTSON and J. M. BINNS (Lucas Aerospace, Ltd., Engine and Electronic Systems Div., Birmingham, United Kingdom) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 8.1-8.7.
Copyright

After defining aircraft engine systems for safety and reliability, attention is given to the ways in which system options influence engine reliability, as well as to how current full authority digital engine control (FADEC) systems have evolved to meet these reliability and integrity requirements. Also noted is how fault-tolerance and analytical redundance philosophies can be used to improve dispatch capability. The requirements for civil extended-range twin-engined transports, or 'ETOPS', are noted to be major drivers toward the next major developmental step in engine-control systems design. Also noted is the role to be played by hydromechanical and electronic hardware and software improvements. O.C.

A93-18787
ENGINE HEALTH MONITORING
M. COLLINS (SD-Scicon UK, Ltd., Hook, United Kingdom) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 9.1-9.5.
Copyright

Engine Health Monitoring (EHM) of aircraft powerplants can yield highly flexible, computer-based reliability evaluations over the course of operational life. The EHM reliability-evaluation process is rendered more accessible to the end-user with the arrival of programs which allow the interactive investigation of problems, while enlisting the display capabilities of personal computers and workstations. Onboard Automatic Condition Monitoring Systems can be used to automate EHM data-entry. O.C.

A93-18790
USING ADVANCED TECHNOLOGY TO ACHIEVE RELIABILITY AS WELL AS HIGH PERFORMANCE
E. C. BRYAN (Pratt & Whitney Group, West Palm Beach, FL) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 12.1-12.13.
Copyright

A development history and current status evaluation are presented for the efforts of a major military engine manufacturer to tailor novel technologies in ways that achieve a balance between improvements in performance and in reliability. Attention is given to the progressive application of technology improvements to the F100 engine's -200, -220, and -229 variants; also noted is the further application of the lessons thus gained to the 'integrated product development' program of the F119-PW-100 engine of the F-22 fighter. O.C.

A93-19121
THEORETICAL INVESTIGATION OF COMBUSTION CHARACTERISTICS IN RAM-JET DUMP COMBUSTOR WITH SIDE-INLET
SHU-HAO CHUANG (National Chung Hsing Univ., Taichung, Taiwan), HSUN-CHENG LIN (Shu-Teh Junior College of Technology, Taichung, Taiwan), MING-HUA CHEN (Chung-Chou Inst. of Technology, Chunghuax, Taiwan), and JIN-FA JAN (Feng-Chia Univ., Taichung, Taiwan) International Journal for Numerical Methods in Fluids (ISSN 0271-2091) vol. 15, no. 10 Nov. 30, 1992 p. 1197-1212. refs
Copyright

The combustion flow of a sudden-expansion dump combustor with injecting side-inlet is analyzed using the SIMPLE-C algorithm and the Jones-Launder k-epsilon two-equation turbulence model. The transport properties of velocity, turbulence kinetic energy, temperature and combustion efficiency as a function of the injected mass fraction and the number of side-inlet nozzles are solved in this paper. The axial velocities of the sudden-expansion dump combustor without injected side-inlet flow are solved first and found to be in good agreement with the experimental data of Moon and Rudinger. For a fixed value of the side-inlet number the wall temperature and combustion efficiency of the dump combustor are decreased when the injected mass fraction is increased. For a fixed value of the injected mass fraction the wall temperature and combustion efficiency are decreased when the number of side-inlet nozzles is increased. Author

A93-19279* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COUPLED MULTI-DISCIPLINARY SIMULATION OF COMPOSITE ENGINE STRUCTURES IN PROPULSION ENVIRONMENT
CHRISTOS C. CHAMIS (NASA, Lewis Research Center, Cleveland, OH) and SURENDRA N. SINGHAL (Sverdrup Technology, Inc., Cleveland, OH) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Previously announced in STAR as N92-23267 refs
(ASME PAPER 92-GT-6)

A computational simulation procedure is described for the coupled response of multi-layered multi-material composite engine structural components which are subjected to simultaneous multi-disciplinary thermal, structural, vibration, and acoustic loadings including the effect of hostile environments. The simulation is based on a three dimensional finite element analysis technique in conjunction with structural mechanics codes and with acoustic analysis methods. The composite material behavior is assessed at the various composite scales, i.e., the laminate/ply/constituents (fiber/matrix), via nonlinear material characterization model. Sample cases exhibiting nonlinear geometrical, material, loading, and environmental behavior of aircraft engine fan blades, are presented. Results for deformed shape, vibration frequency mode shapes, and acoustic noise emitted from the fan blade, are discussed for their coupled effect in hot and humid environments. Results such as acoustic noise for coupled composite-mechanics/heat transfer/structural/vibration/acoustic analyses demonstrate the effectiveness of coupled multi-disciplinary computational simulation the various advantages of composite materials compared to metals. Author

A93-19283
A NUMERICAL INVESTIGATION INTO THE NOZZLE FLOW OF HIGH BY-BASS TURBOFANS
H. ZIMMERMANN, K. KATHEDER, and A. JULA (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Germany) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-10)

Standard numerical methods for investigating the nozzle flow of high-bypass turbofans are reviewed. Two new parameters for high-bypass turbofans are proposed for correlating the engine thrust and for evaluating the influence of the overall size of the nacelle.
I.S.

A93-19285
ANALYSIS OF HIGH SPEED MULTISTAGE COMPRESSOR THROUGHFLOW USING SPANWISE MIXING
J. DUNHAM (Defence Research Agency, Farnborough, United Kingdom) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-13) Copyright
The Gallimore/Cumpsty model of spanwise mixing is incorporated into the Royal Aircraft Establishment streamline curvature program, verified against simple test cases, and applied to analyze the C147 build 1 traverses. A plausible model was constructed manually, based on a simple model of endwall loss and deviation effects that accounted for the observed radial distributions of stagnation temperature, pressure and flow angles. This model indicates that a wall stall occurs at the hub of the first rotor, and the resulting low energy fluid flows outward as it progresses through subsequent blade rows, causing local changes in traverse patterns and by annulus wall boundary layer predictions.
R.E.P.

A93-19286
LIFTING SURFACE THEORY FOR STEADY AERODYNAMIC ANALYSIS OF DUCTED COUNTER ROTATION PROPFAN
HIDEKAZU KODAMA (Ishikawajima-Harima Heavy Industries, Co., Ltd., Tokyo, Japan) and MASANOBU NAMBA (Kyushu Univ., Fukuoka, Japan) Jun. 1992 14 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-14)
A lifting surface theory is developed to predict the steady performance for ducted counter rotation propfan with blade sweep. In solving the integral equation, the chordwise lifting pressures on the blade surfaces of front and rear rotors are expanded into a finite series at each radial collocation point, and the coefficients of the series are determined so that the blade surface flow tangency conditions for both rotors are satisfied at the corresponding number of control points. Calculations are carried out for the propfans with subsonic relative flows, and the effect of the number of blades on the total pressure rise is studied using a probable blade model. The interference effect between the rotors and the effect of blade sweep on the steady performance are also demonstrated.
Author

A93-19297
INFLUENCE OF A THERMAL BARRIER COATING ON THE PERFORMANCE OF A TURBOPROP ENGINE
J. D. MACLEOD (National Research Council of Canada, Ottawa) and J. C. G. LAFLAMME (DND, Ottawa, Canada) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-38)
The efforts of the Canadian Department of National Defense, the Engine Laboratory of the National Research Council of Canada, to evaluate the influence of applying a thermal barrier coating on the performance of a gas turbine engine are discussed. The project is aimed at quantifying the performance effects of a particular ceramic coating on the first stage turbine vanes. Attention is given to the effect of coating thickness on nozzle effective flow area, and the influence of surface roughness on turbine efficiency. The results of the coating study indicated that the measured performance shifts are generally within the expected measurement uncertainty. These changes are thermodynamically consistent given the fact that the thermal barrier coating is thinner at the nozzle throat area and rougher than the normal nozzle protective coatings. The increase in the effective flow area caused a minor engine cycle rematch, with no appreciable change in overall engine performance. The only noticeable effects of the coating were on the corrected airflow, turbine efficiency, and turbine pressure ratio.
P.D.

A93-19300
A SYSTEMS DYNAMICS APPROACH TO MODELING GAS TURBINE COMBUSTOR WEAR
B. BAGEPALLI, S. DINC, I. IMAM, J. BARNES, and C. SLOCUM (General Electric Co., Schenectady, NY) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-47)
The development of the basic understanding of dynamic and wear problems of combustor systems is investigated. A systems dynamic modeling approach is developed employing a general purpose dynamic/wear analysis program (mechanism analysis program). The goal is to develop a generic design/analysis tool for the rapid evaluation of preliminary designs and for detailed design studies to create enhanced/optimized combustor designs from a wear/life perspective.
R.E.P.

A93-19304
ONE-DIMENSIONAL METHODS FOR ACCURATE PREDICTION OF OFF-DESIGN PERFORMANCE BEHAVIOR OF AXIAL TURBINES
T. SCHOBEIRI (Texas A & M Univ., College Station) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-54)
The turbine component of a gas turbine engine is frequently subjected to extreme operation conditions associated with significant changes in mass flow, turbine inlet temperature, pressure and rotational speed. These off-design operation conditions significantly affect the flow deflection within the turbine stage, which consists of individual stator and rotor rows. As a result, the stage parameters representing the velocity diagram will change and effect the efficiency and performance of the stage and, thus, the turbine. A differential and integral method is presented for predicting the performance behavior of turbines under extreme off-design conditions. Both methods are applied to a multistage turbine for which the off-design performance is calculated and compared with the measurement.
Author

A93-19305
AN INVESTIGATION OF POST STALL TRANSIENTS AND RECOVERABILITY OF AXIAL COMPRESSION SYSTEMS. I - A SIMPLIFIED METHOD
JUN HU, GUO C. TANG, and HUI M. ZHANG (Nanjing Aeronautical Inst., China) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-55)
A simple approximate technique based on the theory developed by Moore and Greitzer (1985) is proposed to predict when pure surge, or pure rotating stall exist. The technique leads to a set of three simultaneous nonlinear first order partial differential equations and for the numerical solutions, a simple time-marching technique can be employed. It is shown that an investigation of rotating-stall-like and surge-like motion, recoverability from rotating stall or surge, and limited parameters can be performed through this technique.
R.E.P.

A93-19306
AN INVESTIGATION OF POST STALL TRANSIENTS AND RECOVERABILITY OF AXIAL COMPRESSION SYSTEMS. II - NUMERICAL SIMULATIONS
JUN HU, GUO C. TANG, and HUI M. ZHANG (Nanjing Aeronautical Inst., China) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-56)
By using the previously developed method, the calculations of limited parameters, recovery behaviors from stalled flow and the

effect of compression system parameters on the recoverability from rotating stall are performed. The calculations of transient recovery behaviors from stalled flow surge or rotating stall are conducted and show that the method can be employed to investigate these problems. The numerical results are shown to be consistent with experimental data. R.E.P.

A93-19307* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
STABILITY OF FULLY DEVELOPED ROTATING STALL
F. E. MCCAUGHAN and HONG X. XUE (Case Western Reserve Univ., Cleveland, OH) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract NAG3-1179)
(ASME PAPER 92-GT-57)

In McCaughan (1989b) it was observed that the slopes of both the axisymmetric and rotating stall characteristics play a major role in determining the mode of instability of the engine and the recovery point. That analysis was carried out for the grossly simplified model where the stall cell was considered as a traveling sine wave. That work has been extended to the more reasonable situation where the stall cell is represented by forty Fourier modes. The results from the simple model of three ordinary differential equations are discussed in the light of the more realistic calculations. In particular we discuss the effects of two parameters: the steepness of the axisymmetric characteristic and the shutoff head. Author

A93-19308
A WIDE-RANGE AXIAL-FLOW COMPRESSOR STAGE PERFORMANCE MODEL
GREGORY S. BLOCH and WALTER F. O'BRIEN (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by USAF and U.S. Army refs
(ASME PAPER 92-GT-58)

Dynamic compression system response is a major concern in the operability of aircraft gas turbine engines. Multi-stage compression system computer models have been developed to predict compressor response to changing operating conditions. These models require a knowledge of the wide-range, steady-state operating characteristics as inputs, which has limited their use as predicting tools. The full range of dynamic axial-flow compressor operation spans forward and reversed flow conditions. A model for predicting the wide flow range characteristics of axial-flow compressor stages was developed and applied to a 3-stage, low-speed compressor with very favorable results and to a 10-stage, high-speed compressor with mixed results. Conclusions were made regarding the inception of stall and the effects associated with operating a stage in a multistage environment. It was also concluded that there are operating points of an isolated compressor stage that are not attainable when that stage is operated in a multi-stage environment. Author

A93-19318
SIMULATION OF THE SECONDARY AIR SYSTEM OF AERO ENGINES
K. J. KUTZ and T. M. SPEER (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Germany) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-68)

This paper describes a computer program for the simulation of secondary air systems. Typical flow system elements are presented, such as restrictors, tappings, seals, vortices, and coverplates. Two-phase flow as occurring in bearing chamber vent systems is briefly discussed. The algorithm is described for the solution of the resulting nonlinear equations. The validity of the simulation over the engine operation envelope is demonstrated by a comparison with test results. Author

A93-19323
DESIGN AND ROTOR PERFORMANCE OF A 5:1 MIXED-FLOW SUPERSONIC COMPRESSOR
R. MOENIG (Rheinmetall GmbH, Duesseldorf, Germany), W. ELMENDORF, and H. E. GALLUS (Aachen, Rheinisch-Westfaelische Technische Hochschule, Germany) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-73)

Analytical considerations for mixed-flow supersonic compressors with strong shock waves are presented. The results and flow analysis obtained by extensive experimental investigations of the designed mixed-flow compressor rotor are described. Massflow, total pressure rise and efficiency show good agreement with the design properties for near-surge operation at design and off-design conditions. R.E.P.

A93-19331
FAULT SIGNATURES OBTAINED FROM FAULT IMPLANT TESTS ON AN F404 ENGINE
RICHARD W. EUSTACE, BRUCE A. WOODYATT, GRAEME L. MERRINGTON, and TONY A. RUNACRES (Defence Science and Technology Organisation, Aeronautical Research Lab., Melbourne, Australia) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Royal Australian Air Force refs
(ASME PAPER 92-GT-82)

The fault diagnostic process for gas turbine engines can be improved if data acquired by an on-board engine monitoring system (EMS) are utilized effectively. In the commercial transport field, techniques are available to extract engine condition assessment information from steady-state EMS data. In a military environment, steady-state data are not always available, and therefore it is desirable to extract at least some of the information from transient data, such as during take-off. Fault signatures are presented for an F404 engine based on fault implant tests in a sea-level-static (SLS) test-cell. A comparison is then made between the fault coverage capabilities of fault diagnostic techniques based on the use of steady-state engine data with those using transient data. The important conclusions to emerge from this work are that for the range of faults examined, not only is there similar fault information contained within the transient data but the faults can be detected with increased sensitivity using these data. Author

A93-19332
THE EFFECT OF COMPRESSOR ROTOR TIP CROPS ON TURBOSHAFT ENGINE PERFORMANCE
PETER C. FRITH (Defence Science and Technology Organisation, Aeronautical Research Lab., Melbourne, Australia) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-83)

The results from an experimental study into the effect of compressor rotor tip clearance changes on the steady-state performance and stability margins of a free-power turbine turboshaft engine are presented and discussed. This work was directed at the development of methods to diagnose engine condition from gas path measurements. It was found that the normal production suite of engine instrumentation was able to measure the deterioration in engine performance due to the implanted compressor degradation and the resultant deviations in the measured parameters from their respective nominal baselines do provide useful indicators of engine condition. Author

A93-19335
ACTIVE STABILIZATION OF COMPRESSOR INSTABILITY AND SURGE IN A WORKING ENGINE
J. E. F. WILLIAMS (Cambridge Univ., United Kingdom), M. F. L. HARPER, and D. J. ALLWRIGHT (Topexpress, Ltd., Cambridge, United Kingdom) Jun. 1992 13 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne,

Germany, June 1-4, 1992 Research supported by U.S. Navy refs
(ASME PAPER 92-GT-88)

We have applied feedback control to the compressor of a 45 kW auxiliary power unit. Using this, the engine is able to deliver more than 10 percent extra shaft power before surge occurs. We achieve control by suppressing a non-axisymmetric flow phenomenon in the diffuser of the centrifugal compressor. Control is effected by modulating a small extra air flow into the impeller. We present results of modeling and analysis which suggest that linear feedback control will be sufficient to stabilize a compression system, even when both axisymmetric surge and rotating stall are present as possible instabilities. Author

A93-19338
THE EFFECTS OF BLADE LOADING IN RADIAL AND MIXED FLOW TURBINES
H. CHEN, M. ABIDAT, N. C. BAINES (Imperial College of Science, Technology, and Medicine, London, United Kingdom), and M. R. FIRTH (Holset Engineering Co., Ltd., Huddersfield, United Kingdom) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-92)

Understanding of the effects of blade loading and blade number in radial and mixed flow turbines is often based on analogies with axial turbine cascade tests or centrifugal compressors rather than direct measurement. In this paper test results from a series of similar mixed flow turbines are described. The turbine rotors differ only in blade number or inlet incidence variation. The results comprise performance data and hub and shroud pressure measurements, from which it is possible to deduce parameters such as incidence angle with good accuracy. In addition, predictions of blade loading using three-dimensional computations are shown. The results are correlated against a loading coefficient and a slip factor, both derived for the general case of a mixed flow turbine. The influence of these parameters on the performance of the tested turbines, and for comparison of other radial turbines, is shown. Author

A93-19339
THE DESIGN AND EVALUATION OF A HIGH PRESSURE RATIO RADIAL TURBINE
K. R. PULLEN, N. C. BAINES (Imperial College of Science, Technology, and Medicine, London, United Kingdom), and S. H. HILL (Rolls-Royce, PLC, Leavesden, United Kingdom) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-93)

Attention is given to a single-stage high-speed high pressure ratio radial inflow turbine designed for a single shaft gas turbine engine in the 200-kW power range. A model turbine was tested in a cold rig facility with correct simulation of the important nondimensional parameters. Performance measurements over a wide range of operation are conducted, together with extensive volute and exhaust traverses, so that gas velocities and incidence and deviation angles could be deduced. The turbine efficiency is lower than expected at all but the lowest speed. The rotor incidence and exit swirl angles, as obtained from the rig test data, are very similar to the design assumptions. Evidence of a region of separation in the nozzle vane passages, presumably caused by a very high curvature in the endwall just upstream of the vane leading edges, is found. The effects of such a separation are shown to be consistent with the observed performance. C.A.B.

A93-19340
AERODYNAMIC DESIGN OF PIVOTABLE NOZZLE VANES FOR RADIAL-INFLOW TURBINES
M. SCHOELCH (Univ. der Bundeswehr, Hamburg, Germany) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-94)

To enhance the efficiency of a radial inflow turbine new inl guide vanes have been developed. The design is the result iteratively changing the outline of the blade contour and subseque aerodynamic study of the new cascade generated. The efficienc of the turbine is measured in operation with the original and th new guide vanes at different nozzle positions and pressure ratios The total-to-static efficiency of the turbine increased in all measured points (some points by two percent). R.E.P.

A93-19346
MODIFICATION OF COMBUSTOR STOICHIOMETRY DISTRIBUTION FOR REDUCED NO(X) EMISSION FROM AIRCRAFT ENGINES
G. J. STURGESS, R. MCKINNEY, and S. MORFORD (Pratt & Whitney Group, East Hartford, CT) Jun. 1992 14 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-108)

Measurements of the emissions from an experimental engine were analyzed to construct a design chart for the reduction of oxides of nitrogen NO(x) in conventional combustors. The design chart was used to reconfigure the stoichiometry distribution of the combustor of a production engine so as to reduce NO(x) while holding the emissions of carbon monoxide, unburned hydrocarbons and smoke well below existing regulations. Combustion section pressure loss and combustor outlet temperature distributions were substantially unchanged. The modified design was refined with the aid of computational fluid dynamics calculations to optimize the emissions reduction. Worthwhile reductions in NO(x) were obtained with combustor modifications that are transparent to the engine user. Author

A93-19347
EMISSIONS REDUCTION BY VARYING THE SWIRLER AIRFLOW SPLIT IN ADVANCED GAS TURBINE COMBUSTORS
GERALD J. MICKLOW, SUBIR ROYCHOUDHURY (Florida Univ., Gainesville), H. L. NGUYEN (NASA, Lewis Research Center, Cleveland, OH), and MICHAEL C. CLINE (Los Alamos National Lab., NM) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-110)

A rich burn/quick mix/lean burn (RQL) combustor concept for reducing pollutant emissions is currently under investigation at the NASA Lewis Research Center. The current study investigates the effect of varying the mass flow rate split between the swirler passages for an equivalance ratio of 2.0 on fuel distribution, temperature distribution, and emissions for the fuel nozzle/rich burn section of an RQL combustor. It is seen that optimizing these parameters can substantially improve combustor performance and reduce combustor emissions. The optimal mass flow rate split for reducing NO(x) emissions based on the numerical study was the same as found by experiment. Author

A93-19351
NO(X) SENSITIVITIES FOR GAS TURBINE ENGINES OPERATED ON LEAN-PREMIXED COMBUSTION AND CONVENTIONAL DIFFUSION FLAMES
DAVID NICOL, PHILIP C. MALTE, JENKIN LAI, NICK N. MARINOV, DAVID T. PRATT (Washington Univ., Seattle), and ROBERT A. CORR (General Electric Co., Schenectady, NY) Jun. 1992 14 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Univ. of Washington refs
(ASME PAPER 92-GT-115)

The paper examines NO(x) exhaust emissions for gas turbine engines with lean-premixed combustors as a function of the combustor pressure (P), mean residence time (tau), fuel-air equivalence ratio (phi), and inlet mixture temperature (Ti). The fuel is methane. The study is conducted through chemical reactor modeling of the combustor, using CH4 oxidation and NO(x) kinetic mechanisms currently available. The NO(x) is formed by the Zeldovich, prompt, and nitrous oxide mechanisms. The pressure

sensitivity of the NO(x) is examined. This is found to be minimum, and essentially nil, when the conditions are P = 1 to 10 atm, Ti = 600 K, and phi - 0.6. The source of the NO(x) is also examined. For the combustor as a whole, the nitrous oxide mechanism predominates over the prompt mechanism, and for phi of 0.5 to 0.6, competes strongly with the Zeldovich mechanism. For phi greater than 0.6 to 0.7, the Zeldovich mechanism is the predominant source of the NO(x) for the combustor as a whole.
C.A.B.

A93-19355
IGNITION AND EXHAUST EMISSION CHARACTERISTICS OF SPRAY COMBUSTION IN A PRE-CHAMBER TYPE VORTEX COMBUSTOR
YOUICHIROU OHKUBO, YOSHIHIRO NOMURA, YOSHINORI IDOTA (Toyota Central R&D Labs., Inc., Nagakute, Japan), and YOSHIHISA GUNJI (Toyota Motor Corp., Susono, Japan) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-119)
An experimental investigation has been conducted of the ignition limit, the lean blowout limit, and the exhaust emission characteristics of spray combustion is presently conducted for a prechambered vortex combustor for a 300 kW gas turbine engine. These three characteristics are shown to depend on the spray characteristics of the fuel injector and the airflow pattern of air in the chamber. Ignition proceeds through the formation of a flame kernel near the ignitor, the propagation of the kernel into the flameholding region, and the formation of a rotating flame in the flameholding region. O.C.

A93-19357
INVESTIGATION OF COMBUSTION STRUCTURE INSIDE LOW NO(X) COMBUSTORS FOR A 1500 C-CLASS GAS TURBINE
H. MATSUZAKI (Tohoku Electric Power Co., Inc., Sendai, Japan), I. FUKUE, S. MANDAI, S. TANIMURA, and M. INADA (Mitsubishi Heavy Industries, Ltd., Takasago, Japan) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-123)
This paper describes the cold flow tests and low pressure combustion tests which were conducted for the development of a 1500 C-class low NO(x) combustion system. In the cold flow tests, the effect of vane angle and the momentum ratio of fuel to air flow on mixing characteristics inside the premixing nozzles was investigated. The stabilization of the flow field inside the combustor was confined by measurement of the axial velocity distribution and observations by using a tuft of soft thread. Combustion characteristics in terms of emissions and stability were investigated initially by low pressure combustion tests, and the gas temperature distribution inside the combustor was measured. NO(x) emissions for a 1500 C-class gas turbine as low as 50 ppm at 15 percent oxygen at design pressure were demonstrated. Author

A93-19359
THE COMBINED CLOSED FORM-PERTURBATION APPROACH TO THE ANALYSIS OF MISTUNED BLADED DISKS
MARC P. MIGNOLET and CHUNG-CHIH LIN (Arizona State Univ., Tempe) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Allied-Signal Aerospace Co refs
(ASME PAPER 92-GT-125)
A two-step method is presented for the determination of reliable approximations of the probability density function of the forced response of a randomly mistuned bladed disk. Under the assumption of linearity, an integral representation of the probability density function of the blade amplitude is first derived. Then, deterministic perturbation techniques are employed to produce simple approximations of this function. The adequacy of the method is demonstrated by comparing several approximate solutions with simulation results. Author

A93-19363
THREE-DIMENSIONAL GAS TURBINE COMBUSTOR EMISSIONS MODELING
N. K. RIZK and H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-129)
An emission model that combines the analytical capabilities of 3D combustor performance codes with mathematical expressions based on detailed chemical kinetic scheme is formulated. The expressions provide the trends of formation and/or the consumption of NO(x), CO, and UHC in various regions of the combustor utilizing the details of the flow and combustion characteristics given by the 3D analysis. By this means, the optimization of the combustor design to minimize pollutant formation and maintain satisfactory stability and performance could be achieved. The developed model was used to calculate the emissions produced by several engine combustors that varied significantly in design and concept, and operated on both conventional and high density fuels. The calculated emissions agreed well with the measurements. The model also provided insight into the regions in the combustor where excessive emissions were formed, and helped to understand the influence of the combustor details and air admission arrangement on reaction rates and pollutant concentrations. Author

A93-19365
INNOVATIVE HIGH TEMPERATURE AIRCRAFT ENGINE FUEL NOZZLE DESIGN
R. W. STICKLES, W. J. DODDS (GE Aircraft Engines, Cincinnati, OH), T. R. KOBLISH, J. SAGER (Fuel Systems Textron, Inc., Zeeland, MI), and S. CLOUSER (U.S. Navy, Naval Air Propulsion Center, Trenton, NJ) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract N00140-87-C-6321)
(ASME PAPER 92-GT-132)
An innovative, single-inlet dual-orifice fuel nozzle has been designed to operate at maximum combustor air and fuel temperatures of 1144 K and 450 K, respectively. The design's approach involved the minimization of fuel passage wetted-wall temperatures with improved heat shielding, and to reduce the fuel-coking rate by treating the fuel-passage surfaces. Heat-transfer analysis has shown that polishing the fuel passage reduced the coking rate, and that the type of deposition depended on the wetted wall temperature. O.C.

A93-19370
THREE COMPONENT LDV VELOCITY MEASUREMENTS IN A CAN TYPE RESEARCH COMBUSTOR FOR CFD VALIDATION. I - ISOTHERMAL
SAAD A. AHMED (USAF, Wright Lab., Wright-Patterson AFB, OH), ALAN ROSE (Rolls-Royce, Inc., Dayton, OH), and ABDOLLAH S. NEJAD (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1992 15 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-138)
A two-component fiber optic LDV system has been employed to measure three mean velocity components and five Reynolds stress components in a confined, isothermal strongly swirling flowfield. The primary objective is to provide complete benchmark data for comparisons with numerical predictions based on practical models for turbulent swirling flows and thereby guide the development of such models. Results of initial modeling work are presented, and the superiority of the Reynolds stress modeling approach is clearly illustrated through comparisons with the results from experiment and a typical k-epsilon model. Measurements show the radial velocity component (close to the swirler exit) to be of the same magnitude as the axial and swirl components. Author

A93-19375
AN UPDATE ON THE DEVELOPMENT OF THE T407/GLC38 MODERN TECHNOLOGY GAS TURBINE ENGINE
MICHAEL J. ZOCCOLI and KENNETH P. RUSTERHOLZ (Textron Lycoming, Stratford, CT) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-147)
A development status report is presented for the advanced, single-spool gas generator module-employing T407 6000-shp-class turboprop/turbofan engine. A comprehensive review is conducted of the test objectives and requirements, setup, and basic results obtained; attention is given to the relevancy of each stage of engine testing to the qualification/certification goals formulated. O.C.

A93-19376
BLADE EXCITATION BY CIRCUMFERENTIALLY ASYMMETRIC ROTATING STALL IN CENTRIFUGAL COMPRESSORS
D. JIN, U. HAUPT, H. HASEMANN, and M. RAUTENBERG (Hanover Univ., Germany) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by DFG refs
(ASME PAPER 92-GT-148)
Consideration is given to the excitation of blade vibration by circumferentially asymmetric rotating stall in a high pressure ratio, high mass flow centrifugal compressor with radial impeller, and vaned diffusers. Detailed analyses of blade analyses of blade vibration by very strong rotating stall in the speed range of 13,000-14,500 rpm displayed multiple frequency components of blade vibration besides the main excitation frequency caused by rotating stall. The frequency values were found to be related to frequencies of shaft rotation and rotating stall. Two-dimensional Fourier analysis for the pressure pattern of rotating stall is used to develop a calculation method for blade vibration frequencies by circumferentially asymmetric rotating stall. The predicted blade vibration frequencies corresponded to the frequency components of the blade vibration spectrum obtained from the strain gages. P.D.

A93-19377
EXCITATION OF BLADE VIBRATION DUE TO SURGE OF CENTRIFUGAL COMPRESSORS
D. JIN, U. HAUPT, H. HASEMANN, and M. RAUTENBERG (Hanover Univ., Germany) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by DFG refs
(ASME PAPER 92-GT-149)
An investigation of blade excitation during surge in a high performance single stage centrifugal compressor with various impeller and diffuser geometry is presented. The blade vibration was measured using blade mounted strain gages. The flow characteristics during surge as the cause of blade excitation were simultaneously determined by fast response dynamic pressure transducers. It is shown that, in addition to the excitation of rotating stall during surge, strong nonperiodic pressure fluctuations at the beginning and the end of the surge induced dangerous blade excitations in all compressor configurations. The maximum strain values of blade vibration for all compressor versions at different rotational speeds of the compressure were measured to estimate the danger of blade excitation during surge. It is shown that the blade excitation during the compressor surge with vaned diffusers is stronger than the excitation with a vaneless diffuser and that the blade excitation with a radial impeller is stronger than the excitation with a backswept impeller. P.D.

A93-19389
OPTIMIZATION OF A MULTISTAGE AXIAL COMPRESSOR STOCHASTIC APPROACH
I. N. EGOROV (Air Force Engineering Academy, Moscow, Russia) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-163)
A procedure of a multistage axial compressor (MAC) parameters optimization in stochastic setting has been offered. The procedure allows to obtain a stable solution from the point of view of its practical realization. A concept of robustness (stability) of turbomachine optimum design has been introduced, and the criteria of stability degree evaluation of complex technical objects optimum solution have been also suggested. With reference to determining optimum laws to control the rows of MAC, modeled in 2D axisymmetric setting, there are presented the results of the comparative analysis of the solutions obtained both with using the traditional (deterministic) approach and the proposed stochastic setting, which allows to increase the possibility to realize the technical solution by more than two times. Analysis of the results shows that the value of optimization criterion obtained in stochastic setting doesn't practically worsen the value of optimization criterion obtained in deterministic approach. Author

A93-19393
COMPUTATIONAL TECHNIQUES FOR PROBABILISTIC ANALYSIS OF TURBOMACHINERY
H. R. MILLWATER, A. J. SMALLEY, Y.-T. WU, T. Y. TORNG, and B. F. EVANS (Southwest Research Inst., San Antonio, TX) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-167)
Some advanced computational techniques for probabilistic analysis of turbomachinery are reported. A description of the requirements for probabilistic analysis and several solution methods are summarized. The traditional probabilistic analysis method, Monte Carlo simulation, and two advanced techniques, the advanced mean value (AVM) method and importance sampling, are discussed. The performance of the Monte Carlo, AMV, and importance sampling methods is explored through a forced response analysis of a two degree-of-freedom Jeffcott rotor model. Variations in rotor weight, shaft length, shaft diameter, Young's modulus, foundation stiffness, bearing clearance, viscosity, and length are considered. The AMV and importance sampling methods are shown to give accurate solutions with a far smaller number of simulations than the Monte Carlo method. These methods make it possible to perform accurate and efficient probabilistic analysis of realistic complex rotor dynamic models. P.D.

A93-19396
ADVANCES IN THE NUMERICAL INTEGRATION OF THE 3-D EULER EQUATIONS IN VIBRATING CASCADES
GEORG A. GEROLYMOS (Paris VI, Univ., France) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by SNECMA refs
(ASME PAPER 92-GT-170)
In the present work an algorithm for the numerical integration of the 3D unsteady Euler equations in vibrating transonic compressor cascades is described. The equations are discretized in finite-volume formulation in a mobile grid using isoparametric brick elements. They are integrated in time using Runge-Kutta schemes. A thorough discussion of the boundary-conditions used and of their influence on results is undertaken. The influence of grid refinement on computational results is examined. Unsteady convergence of results is discussed. Author

A93-19397
COUPLED 3-D AEROELASTIC STABILITY ANALYSIS OF BLADED DISKS
GEORG A. GEROLYMOS (Paris VI, Univ., France) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by SNECMA refs
(ASME PAPER 92-GT-171)
In the present work an algorithm for the coupled aeromechanical

computation of 3D compressor cascades vibrating in a traveling-wave mode is presented and applied to the determination of aeroelastic stability of a transonic fan rotor. The initial vibratory modes are computed using a finite-element structural analysis code. The unsteady flowfield response to blade vibration is estimated by numerical integration of the 3D unsteady Euler equations. Coupling relations are formulated in the frequency domain, using a mode-modification technique, based on modal projection. The vibratory mode is updated at the end of the aerodynamic stimulation of each period, and the updated mode is used for the simulation of the next period. A number of results illustrate the method's potential. Author

A93-19398
AN ANALYSIS SYSTEM FOR BLADE FORCED RESPONSE
HSIAO-WEI D. CHIANG and ROBERT E. KIELB (GE Aircraft Engines, Cincinnati, OH) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-172)

A novel analysis system to predict blade forced response is described. The system provides a design tool, over and above the standard Campbell diagram approach, for predicting potential forced response problems. The incoming excitation sources are modeled using a semiempirical rotor wake/vortex model for wake excitation, measured data for inlet distortion, and a quasi-3D Euler code for pressure disturbances. These aerodynamic stimuli, the blade's natural frequencies, and mode shapes from an FEM are used to calculate the unsteady aerodynamic modal forces and the aerodynamic damping. A model response solution is performed. This system's application to current engine designs is examined. Specifically, the fan blade response due to inlet distortion is investigated, and the response of the LPT blades of a counterrotating supersonic turbine is determined. P.D.

A93-19404
EFFECT OF TRAILING-EDGE EJECTION ON LOCAL HEAT (MASS) TRANSFER IN PIN FIN COOLING CHANNELS IN TURBINE BLADES
R. D. MCMILLIN and S. C. LAU (Texas A & M Univ., College Station) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract NSF CBT-87-13833)
(ASME PAPER 92-GT-178)

Experiments are conducted to study the local heat transfer distribution and pressure drop in a pin fin channel that models the cooling passages in modern gas turbine blades. The detailed heat/mass transfer distribution is determined via the naphthalene sublimation technique for flow through a channel with a 16-row, staggered 3 x 2 array of short pin fins (with a height-to-diameter ratio of 1.0, and streamwise and spanwise spacing-to-diameter ratios of 2.5) and with flow ejection through holes in one of the side walls and at the straight flow exit (to simulate ejection through holes along the trailing edges and through tip bleed holes of turbine blades). The pin fin heat/mass transfer and the channel wall heat/mass transfer are obtained for the straight-flow-only and the ejection-flow cases. The results show that the regional pin heat/mass transfer coefficients are generally higher than the corresponding regional wall heat/mass transfer coefficients in both cases. Author

A93-19407
EVALUATION OF APPROACHES TO ACTIVE COMPRESSOR SURGE STABILIZATION
J. S. SIMON, L. VALAVANI, A. H. EPSTEIN, and E. M. GREITZER (MIT, Cambridge, MA) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by U.S. Army and USAF refs
(ASME PAPER 92-GT-182)

A systematic definition of the influence of sensor and actuator selection on increasing the range of stabilized compressor performance is presented. It is shown that proper choice of sensor as well as actuator crucially affects the ability to stabilize compression systems and that, overall, those actuators which are most closely coupled to the compressor appear most effective. The source of the disturbances driving the system, i.e., unsteady compressor pressure rise or unsteady combustor heat release, has a strong influence on control effectiveness, as would be expected for a control problem of this type. General methodologies for the evaluation of active compressor stabilization strategies are delineated, and the performance of several approaches which might be implemented in gas turbine engines is quantified. C.A.B.

A93-19408
AERODESIGN AND PERFORMANCE ANALYSIS OF A RADIAL TRANSONIC IMPELLER FOR A 9:1 PRESSURE RATIO COMPRESSOR
S. COLANTUONI and A. COLELLA (Alfa Romeo Avio S.p.A., Naples, Italy) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-183)

The aerodynamic design of a centrifugal compressor for technologically advanced small aeroengines requires more and more the use of sophisticated computational tools in order to meet the goals successfully at minimum cost development. The objective of the present work is the description of the procedure adopted to design a transonic impeller having 1.31 relative Mach number at the inducer tip, 45 deg back-swept exit blade angle, and a tip speed of 636 m/s. The optimization of the blade shape has been done analyzing the aerodynamic flowfield by extensive use of a quasi-3D code and a fully 3D Euler solver based on a time-marching approach and a finite volume discretization. Testing has been done on the impeller-only configuration, using a compressor rig that simulates a real engine hardware, i.e. having an S-shape air-intake. The overall performance of the impeller are presented and discussed. Author

A93-19410
LOW ASPECT RATIO TRANSONIC ROTORS. I - BASELINE DESIGN AND PERFORMANCE
C. H. LAW (USAF, Wright Lab., Wright-Patterson AFB, OH) and A. R. WADIA (GE Aircraft Engines, Cincinnati, OH) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-185)

The analytical design and experimental test of a single-stage transonic axial-flow compressor are described. This design is the baseline of a compressor design study in which several blade design parameters have been systematically varied to determine their independent effects on compressor performance. The baseline design consisted of ruggedizing an existing compressor design, that demonstrated outstanding aerodynamic performance, to correct some undesirable aeromechanical characteristics. The design study was performed by varying only one design parameter at a time, keeping other design variables as close as possible to the baseline design. Specific design parameters or interest were those for which very little data was available to determine their sensitivity on compressor performance. This paper describes the baseline compressor design and its experimental performance. A detailed definition and flow analysis of the baseline design test point (used as the basis for all subsequent design variations) are provided. Author

A93-19411
LOW ASPECT RATIO TRANSONIC ROTORS. II - INFLUENCE OF LOCATION OF MAXIMUM THICKNESS ON TRANSONIC COMPRESSOR PERFORMANCE
A. R. WADIA (GE Aircraft Engines, Cincinnati, OH) and C. H. LAW (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1992 17 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract F33615-80-C-2059)
(ASME PAPER 92-GT-186)

The design and experimental evaluation of two versions of a low aspect ratio transonic rotor that had the location of the tip blade section maximum thickness moved forward in two increments from the nominal 70 percent to 55 and 40 percent chord length, respectively, is reported. At design speed, the rotor with its maximum thickness located at 55 percent chord length attains higher peak efficiency. A 3D viscous flow analysis is used to identify the performance-enhancing features of the higher-efficiency rotor and to provide guidance in the interpretation of the experimental measurements. It is shown that the difference in performance between the two rotors can be attributed to the higher shock losses that result from the increased leading edge 'wedge angle' as the maximum thickness is moved closer to the leading edge. The higher-efficiency rotor is found to achieve the same static pressure rise potential and loading at a higher flow level than its less-efficient counterpart, and this is responsible for its resulting lower flow rollback and apparent loss in stall margin. C.A.B.

A93-19428
INTEGRATION OF TURBO-EXPANDER- AND TURBO-RAMJET-ENGINES IN HYPERSONIC VEHICLES
B. ZELLNER, W. STERR, and O. HERRMANN (MBB GmbH, Munich, Germany) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-204)
A simulation study is carried out of several configurations of expander-cycle and conventional turbojet engines integrated with ramjet engines for hypersonic aircraft with a flight regime between Mach 0 and 7. The paper presents the engine configurations chosen for the performance studies and describes the computer program used for the propulsion system performance simulation, including all relevant integration aspects. Some results of the propulsion system performance for a generic hypersonic aircraft are presented together with a typical ascent profile. The results of the study indicate that the conventional turbojet cycle is more suitable than the turbo-expander type. I.S.

A93-19448
DESIGN FEATURES INFLUENCING THE DISTRIBUTION OF FUEL WITHIN THE SPRAY FROM AN AIR BLAST FUEL INJECTOR
F. W. STRINGER and A. N. IRWIN (Aero and Industrial Technology, Ltd., Combustion Technology Centre, Burnley, United Kingdom) Jun. 1992 5 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-235)
This paper describes work carried out to determine the influence of several design features upon the performance of an air blast fuel injector. The design features studied were the number of tangential fuel holes feeding the swirl chamber, the depth of the swirl chamber, and the shape of the downstream section of the swirl chamber. The performance parameters considered were, fuel distribution, flow number, air side effective area, spray cone angle and spray SMD. The fuel used was aviation kerosine. Apparatus for the relatively simple and rapid determination of the fuel distribution within the spray is also described. Author

A93-19459
MTR390 - ENGINE FOR THE FUTURE
A. SPIRKL (MTU Motoren- und Turbinen-Union Muenchen, Munich, Germany), J. S. DUCOS (Turbomeca, Bordes, France), and R. THORN (Rolls-Royce, PLC, Bristol, United Kingdom) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-250)
The design of the MTR390, a turboshaft engine in the 1000 kw range, is based on proven technology and components developed well in advance of the actual program start. The engine features a two stage centrifugal compressor, an annular reverse flow ring combustor, a single stage air cooled gas generator turbine, a two stage free power turbine, an integrated reduction and accessory gearbox with integral oil system. A full authority digital engine control provides the engine and system monitoring functions. The development program, which also includes a comprehensive integrated logistics support program, is running according to schedule, more than 1400 engine hours have been logged including 200 flight hours with both a Flying Test Bed and the TIGER prototype helicopter. Author

A93-19462
CONCEPTUAL DESIGN OF TURBO-ACCELERATOR FOR HST COMBINED CYCLE ENGINE
R. YANAGI, M. MORITA (National Aerospace Lab., Tokyo, Japan), Y. WATANABE, H. ITAHARA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan), Y. SASAKI (Kawasaki Heavy Industries Co., Ltd., Tokyo, Japan), and T. AOKI (Mitsubishi Heavy Industries Co., Ltd., Tokyo, Japan) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by MITI refs
(ASME PAPER 92-GT-253)
The turboramjet powerplant currently under development in Japan for a Mach 5-cruise SST/HST commercial transport aircraft that will be both economically viable and environmentally acceptable employs a turbojet for acceleration to Mach 3 and a ramjet cycle for reaching Mach 5 cruise speed. In order to accommodate conflicting cycle requirements, a single-bypass turbofan engine with variable cycle features is joined to a mixer-ejector at the exhaust nozzle. Projected performance data are presented. O.C.

A93-19463
NAVIER-STOKES COMPUTATION ON A PIVOTING DOORS THRUST REVERSER AND COMPARISON WITH TESTS
L. SCHREIBER (SNECMA, Moissy-Cramayel, France) and M. LEGRAS (Hispano-Suiza, Harfleur, France) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-254)
The first application of the present 3D Navier-Stokes-based calculation, accepting small divergences between actual geometry and the meshes derived, has achieved good results in the case of a thrust-reverser door configuration. This design and optimization task has as its goal the four-door thrust-reversal system of the CFM56-5C turbofan engine. The optimization performance obtained is deemed satisfactory. O.C.

A93-19464
RAMJET NOX EMISSION - USE OF A 3D CFD METHOD FOR THE COMBUSTOR DESIGN OF A SUPER/HYPER-SONIC TRANSPORT PROPULSION SYSTEM
E. DAVID, C. BAUDOIN, J. L. SCHULTZ, D. ANSART, and S. MEUNIER (SNECMA, Moissy-Cramayel, France) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by New Energy and Industrial Technology Development Organization of Japan refs
(ASME PAPER 92-GT-255)
A lean premix type injection system based on a low fuel/air ratio combustion that permits a high reduction of NOx emission is presented. A numerical study is conducted to determine the optimal mechanism on carburation homogeneity. The results of a parametric study show the influences of various injection and flame holder systems on air/fuel flow distributions. R.E.P.

A93-19465
SOME TOPICS OF RESEARCH ON HYPERSONIC AIRBREATHING ENGINES AT NATIONAL AEROSPACE LABORATORY
KIMIO SAKATA, HIROYUKI NOUSE, and MITSUHIRO MINODA (National Aerospace Lab., Chofu, Japan) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-256)

A review of various research subjects in Japan related to hypersonic airbreathing engines is presented. These studies include variable cycle engines, combined turbo-ramjet engines, airturbo-ramjet engines and scramjets for commercial space plane propulsion systems. R.E.P.

A93-19485
RESEARCH AND DEVELOPMENT OF CERAMIC TURBINE WHEELS
KEIICHIRO WATANABE, MASAAKI MASUDA, TADAO OZAWA, MINORU MATSUI (NGK Insulators, Ltd., Nagoya, Japan), and KEIJI MATSUHIRO Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-295)
The bending strength of specimens of various sizes, some of which were cut from a turbine wheel, was compared with predictions using Weibull statistical theory. The stress distribution of a ceramic turbine wheel in spin testing was determined with finite elements and the results were used to analyze a wheel that was spun until it burst. The cause of the burst of the ceramic radial turbine wheel at elevated temperature is discussed and based on the tensile rupture data, a design methodology using the Larson Miller parameter was found to be applicable to the ceramic components at elevated temperatures. Author

A93-19487* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
INVESTIGATION OF ROTOR BLADE ROUGHNESS EFFECTS ON TURBINE PERFORMANCE
J. L. BOYNTON, R. TABIBZADEH (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA), and S. T. HUDSON (NASA, Marshall Space Flight Center, Huntsville, AL) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-297)
The cold air test program was completed on the SSME (Space Shuttle Main Engine) HPFTP (High Pressure Fuel Turbopump) turbine with production nozzle vane rings and polished coated rotor blades with a smooth surface finish of 30 microinch (0.76 micrometer) RMS (Root Mean Square). The smooth blades were polished by an abrasive flow machining process. The test results were compared with the air test results from production rough coated rotor blades with a surface finish of up to 400 microinch (10.16 micrometer) RMS. Turbine efficiency was higher for the smooth blades over the entire range tested. Efficiency increased 2.1 percentage points at the SSME 104 percent RPL (Rated Power Level) condition. This efficiency improvement could reduce the SSME HPFTP turbine inlet temperature by 57 degrees Rankine (32 degrees Kelvin) increasing turbine durability. The turbine flow parameter increased and the mid-span outlet swirl angle became more axial with the smooth rotor blades. A.U.T.

A93-19493
INGESTION INTO THE UPSTREAM WHEELSPACE OF AN AXIAL TURBINE STAGE
T. GREEN and A. B. TURNER (Sussex Univ., Brighton, United Kingdom) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-303)
The upstream wheelspace of an axial air turbine stage complete with nozzle guide vanes (NGV's) and rotor blades (430 mm mean diameter) has been tested with the objective of examining the combined effect of NGV's and rotor blades on the level of mainstream ingestion for different seal flow rates. A simple axial clearance seal was used with the rotor spun up to 6650 rpm by drawing air through it from atmospheric pressure with a large centrifugal compressor. The effect of rotational speed was examined for several constant mainstream flow rates by controlling the rotor speed with an air brake. The circumferential variation in hub static pressure was measured at the trailing edge of the NGV's upstream of the seal gap and was found to significantly affect ingestion. The hub static pressure distribution on the rotor blade leading edges was rotor speed dependent and could not be measured in the experiments. The Denton 3D C.F.D. computer code was used to predict the smoothed time dependent pressure field for the rotor together with the pressure distribution downstream of the NGV's. The level and distribution of mainstream ingestion, and thus the seal effectiveness, was determined from nitrous oxide gas concentration measurements and related to static pressure measurements made throughout the wheelspace. With the axial clearance rim seal close to the rotor the presence of the blades had a complex effect. Rotor blades in connection with NGV's were found to significantly reduce mainstream ingestion seal flow rates, but a small level of ingestion existed even for very high levels of seal flow rate. Author

A93-19500
POWDER METALLURGY REPAIR OF TURBINE COMPONENTS
K. A. ELLISON, P. LOWDEN, and J. LIBURDI (Liburdi Engineering, Ltd., Hamilton, Canada) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by National Research Council of Canada refs
(ASME PAPER 92-GT-312)
An advanced powder metallurgy repair process called Liburdi Powder Metallurgy (LPM) has been developed for the repair, overlay or joining nickel and cobalt-based high temperature alloys. This process involves mechanical cleaning, followed by the application and consolidation of a filler metal powder which has substantially the same composition as the base metal, and produces joints with mechanical properties similar to those of the parent material. While previous activated braze or 'widegap' repair processes have been limited to clearances of approximately 1 mm, the LPM technique has the ability to bridge larger gaps of over 5 mm. In addition, the LPM joints contain significantly lower concentrations of melting point depressants such as silicon and boron than conventional wide-gap repair techniques and exhibit superior microstructural features. The characteristics and typical applications of the LPM process for blade and vane repairs are highlighted and the results of laboratory and engine tests are discussed. Author

A93-19501
TEMPER - A GAS-PATH ANALYSIS TOOL FOR COMMERCIAL JET ENGINES
DAVID L. DOEL (GE Aircraft Engines, Evendale, OH) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-315)
Jet engine gas path analysis is utilized to interpret data acquired from overhaul acceptance tests and from aircraft during routine service. The aim is to isolate performance deficiencies to the faulted modules to allow repair to be successfully accomplished. A modern gas-path analysis tool is presented and the benefits and problems experienced by current operators are discussed. R.E.P.

A93-19518
THE COMPARISON OF DIFFERENT SIMPLIFIED MATHEMATICAL MODELS OF THE GAS TURBINE COMBUSTION CHAMBER AS AN OBJECT OF TEMPERATURE AND PRESSURE CONTROL
MAREK DZIDA (Gdansk Technical Univ., Poland) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-347)
The paper presents the mathematical model of the combustion chamber as an object of temperature and pressure control. Using the step function characteristics and the frequency method (in the range of low frequency f below 20 Hz), the theoretical models with different degrees of simplifications were compared with the results of the experimental investigations. Author

A93-19519
EXPERIMENTAL STUDY OF MIXED COMPRESSION AIR-INTAKE FOR HYPERSONIC AIRBREATHING ENGINES
KIMIO SAKATA, RYOJI YANAGI, AKIRA MURAKAMI, SHIGEMI SHINDO (National Aerospace Lab., Tokyo, Japan), SHINJI HONAMI (Tokyo Science Univ., Japan), ATSUSHIGE TANAKA, and KSAZUO SHIRAISHI (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-349)
The results of an experimental study of two air-intake systems of design Mach 4 and 5 with 2D mixed compression are presented. Flow visualization with schlieren and total pressure recovery performance are discussed. The bleed systems at throat, ramp and cowl are adopted and evaluated in terms of stability and pressure recovery. R.E.P.

A93-19524
PERFORMANCE OF GAS TURBINE COMPRESSOR CLEANERS
H. J. KOLKMAN (Nationaal Lucht- en Ruimtevaartlab., Amsterdam, Netherlands) Jun. 1992 5 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Royal Netherlands Air Force and Royal Netherlands Navy refs
(ASME PAPER 92-GT-360)
Deposits are regularly removed from compressor blades and vanes of installed jet engines and gas turbines by compressor washing. Hereby a compressor cleaner is sprayed into the compressor while operating at reduced or normal r.p.m. Recently developed compressor cleaners are claimed to be ecologically sound. In addition, many new compressor cleaners contain a corrosion inhibitor. The cleaning efficiency of eight (old and new) compressor cleaners was determined by means of simulated compressor washing of compressor blades that had become foul in service. For the situation simulated, the cleaning efficiency of new, ecologically sound cleaners turned out to be poor as compared with old compressor cleaners. The corrosion inhibition offered by those cleaners that contain a corrosion inhibitor was found to be satisfactory. Author

A93-19525
MODELS FOR PREDICTING THE PERFORMANCE OF BRAYTON-CYCLE ENGINES
THEODOSIOS KORAKIANITIS (Washington Univ., Saint Louis, MO) and DAVID G. WILSON (MIT, Cambridge, MA) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research sponsored by MIT and International Gas Turbine Inst refs
(ASME PAPER 92-GT-361)
The performance of gas-turbine engines is the result of choices of type of cycle for the application, cycle temperature ratio, pressure ratio, cooling flows and component losses. The output is usually given as efficiency versus specific power. The type of efficiency of interest (thermal, propulsive, specific thrust, overall efficiency) must be specified. This paper presents a set of computer programs for the performance prediction of shaft-power and jet-propulsion cycles, such as simple, regenerative, intercooled-regenerative, turbojet and turbofan cycles. Each cycle is constructed using individual component modules. Realistic default assumptions are made by the programs, or other values can be specified by the user for component efficiencies as functions of pressure ratio, cooling mass-flow rate as a function of cooling technology levels, and various other cycle losses. The programs can be used to predict design point and off-design point operation using appropriate component efficiencies. The effect of various cycle choices on overall performance are discussed. Author

A93-19534
DIRECT NUMERICAL SIMULATION OF NITRIC OXYDE EVOLUTION IN UNDEREXPANDED JETS
RALF J. GATHMANN (Grenoble, Inst. de Mecanique; SNECMA, Moissy-Cramayel, France), CHRISTOPHE BAUDOIN (SNECMA, Moissy-Cramayel, France), and JEAN-PIERRE CHOLLET (Grenoble, Inst. de Mecanique, Moissy-Cramayel, France) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-372)
The evolution of nitric oxides in exhaust jets of aircraft engines is studied by direct numerical simulations. An extended Zeldovich mechanism models the chemical reactions far from equilibrium. For O and O2 molecules equilibrium is assumed. The NO formation can be studied as a function of different parameters, e.g., expansion ratio, jet temperature or jet Mach number. The chemical reactions are highly temperature-dependent leading to high reaction rates in the hot regions behind strong shocks. In particular nearly all NO is formed behind the central shock in the first shock cell. It turns out that for jet exit temperatures of T less than 2000 K only negligible NO - formation in the jet is observed. The NO formation is significant only in hot jets with high expansion ratios. Author

A93-19546
IMPROVING DYNAMIC RESPONSE OF A SINGLE-SPOOL GAS TURBINE ENGINE USING A NONLINEAR CONTROLLER
O. F. QI, N. R. L. MACCALLUM, and P. J. GAWTHROP (Glasgow Univ., United Kingdom) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by British Council refs
(ASME PAPER 92-GT-392)
This paper describes the design of a closed-loop nonlinear controller to improve the dynamic response of a single-spool gas turbine engine. The nonlinear controller is obtained by scheduling the gains of multivariable compensators as a function of engine non-dimensional shaft speed. The compensators, whose outputs are fuel flow and nozzle area, are designed using optimal control theory based on a set of linear models generated from a nonlinear engine simulation. Investigations are also made into developing simple algorithms to obtain an analytical expression for the compressor given its characteristic. The detailed process of developing a nonlinear simulation model for the engine is also described. The open-loop fuel controller is studied using the digital simulation. Author

A93-19550
A COMPACT, INTERCOOLED AND REGENERATED GAS TURBINE FOR HALE APPLICATIONS
JENNIFER J. KOLDEN, WILLIAM J. BIGBEE-HANSEN, and DONALD G. IVERSON (Boeing Defense and Space Group, Seattle, WA) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-401)
A mechanically coupled, two spool, intercooled and regenerated gas turbine engine designed for a high altitude, long endurance (HALE) mission is described. The design philosophy was based on minimization of total energy expended using a two stage optimization process utilizing a multivariable regression and optimization technique. This optimization process addressed the impact of the propulsion system as installed on an air vehicle, including all installation effects. Weight and drag of the complete nacelle as they were affected by the characteristics of the engine was included. A brake specific fuel consumption of 0.262 lb/hr/hp (0.159 kg/hr/Kw) and mission average specific fuel consumption (MSFC) of 0.266 lb/hp-hr (0.160 kg/kW-hr) was estimated for the bare engine and an MSFC of 0.327 lb/hp-hr (0.199 kg/kW-hr) was estimated for the fully installed engine, including the nacelle drag penalty, where MSFC is defined as the total fuel required to complete the mission divided by the total energy expended during the mission. Author

A93-19551
OPTIMIZATION ASPECTS OF AN EJECTOR TYPE HYPERSONIC THRUST NOZZLE
G. TRITTLER, E. ECKERT, and M. GOEING (MTU Motoren- und

Turbinen-Union Muenchen GmbH, Munich, Germany) Jun. 1992 11 p. ASME, *International Gas Turbine and Aeroengine Congress* and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-402)

Hypersonic aircraft projects are highly dependent on efficient propulsion systems. High performance and integration within the airframe play a vital role in the overall concept. Particular attention must be paid to the exhaust system that is submitted to a wide range of operational requirements. An optimization of the nozzle geometry for high flight Mach numbers will lead to a low performance at the transonic flight regime. The additional use of secondary ejector air flow at transonic speeds is one option to improve the thrust behavior of the nozzle. Performance data of single expansion ramp ejector type nozzles are predicted using a calculation model based on a method-of-characteristics algorithm. For optimization purposes the effects of various design parameters on axial thrust coefficient and thrust vector angle are discussed. The geometric parameters investigated are the length of the lower nozzle wall and its deflection angle as well as the ejector slot location and its cross-section. Author

A93-19553
FUEL CELL POWERED ELECTRIC PROPULSION FOR HALE AIRCRAFT
JOHN C. BENTZ (U.S. Navy, Naval Air Development Center, Warminster, PA) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-404)

Electrical energy sources offer some interesting possibilities for aircraft propulsion. Of particular interest are electric propulsion systems developed for aircraft that are designed for high altitude, long endurance (HALE) missions. This class of aircraft would greatly benefit from an aircraft propulsion system which minimizes thermal energy rejection and environmental pollutants. Electric propulsion systems may prove viable for the HALE mission, if reliable energy sources can be developed that are both fuel and weight efficient. Fuel cells are a possible energy source. This paper discusses the thermodynamic cyclic analysis of a fuel cell powered electric propulsion system. In particular, phosphoric acid and polymer electrolyte fuel cells are evaluated as possible energy sources. Author

A93-19554
HIGH PRESSURE RATIO INTERCOOLED TURBOPROP STUDY
C. RODGERS (Sundstrand Power Systems, San Diego, CA) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-405)

The design characteristics and features of a conceptual high pressure ratio intercooled turboprop are discussed. The intended application would be for long endurance aircraft flying at an altitude of 60,000 ft (18,300 m). It is estimated that such a turboprop would be capable of thermal efficiencies exceeding 40 percent with current state-of-the-art component efficiency levels and an overall compressor pressure ratio of 66.0. Projected power (at altitude) to weight ratio is comparable to that of competitive piston and rotary engines. Author

A93-19555
AN OPTIMISATION-MATCHING PROCEDURE FOR VARIABLE CYCLE JET ENGINES
MARCO A. R. NASCIMENTO and PERICLES PILIDIS (Cranfield Inst. of Technology, United Kingdom) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-406)

The problems associated with matching the optimizations of several thermodynamic cycles suited to specific flight conditions in order to configure the components of an integrated, variable-cycle engine are presently addressed by a method based on thermodynamic relationships and component characteristics. While here presented in a mixed numerical-graphical form, the method is easily adapted to fully numerical form for computer implementation. Attention is given to the case of a selective-bleed turbofan. O.C.

A93-19556
SOME ASPECTS OF VARIABLE GEOMETRY GAS TURBINE OPERATION
J. E. A. ROY-AIKINS (Nairobi Univ., Kenya) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-407)

An examination is conducted of a variable-geometry engine suitable for V/STOL aircraft operation, and attention is given to how both mechanical and aerodynamic phenomena associated with variable-area turbines can influence the design, and limit the operation, of future advanced gas turbines. The use of variable-geometry inlet guide vanes and stators to improve the off-design performance of compressors and fans can be extended to include the control of airflow into an engine to modulate thrust at constant shaft rotational speed; this will yield an improvement in engine response rate without loss of thermodynamic performance. O.C.

A93-19558
A SCOPING STUDY FOR HYPERSONIC TRANSPORT PROPULSION SYSTEMS
SIMION C. KUO, JAY D. DOERNBACH, GEORGE CHAMPAGNE (Pratt & Whitney Group, West Palm Beach, FL), A. TATARA, H. FUTAMURA (Kawasaki Heavy Industries, Ltd., Kobe, Japan), Y. WATANABE (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan), and T. AOKI (Mitsubishi Heavy Industries Co., Ltd., Tokyo, Japan) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by New Energy and Industrial Technology Development Organization and HYPR Research Association refs
(ASME PAPER 92-GT-409)

A preliminary study employed to scope the technical challenges and identify the necessary development plans for the hypersonic aircraft propulsion system is presented. Interim results of this scoping study for a turboramjet conceptual design are discussed. Various turboramjet configurations are examined and two promising examples, a coaxial and a split flow configuration are described. R.E.P.

A93-19561
COMBUSTION STUDY ON METHANE-FUEL LABORATORY SCALED RAM COMBUSTOR
Y. KINOSHITA, J. KITAJIMA, M. SHIRAHA (Akashi Technical Inst., Japan), and A. TATARA (Kawasaki Heavy Industries, Ltd., Akashi, Japan) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by New Energy and Industrial Technology Development Organization refs
(ASME PAPER 92-GT-413)

Fundamental flameholding and combustion tests using simple V-gutters for the flame holders were investigated in order to obtain basic design data of a natural gas fueled ram combustor. Then Laboratory Scaled Ram Combustor (LSRC) was designed and fabricated in the first phase of the HYPR project using the fundamental flameholding and combustion tests results. Various tests were conducted to study combustion performance, such as flame stabilization, combustion performance, such as flame stabilization, combustion efficiency, pressure loss and so on, of the LSRC at the simulated conditions of flight Mach number 3. The results indicate that high combustion efficiency is attainable with controlling the concentration of methane air mixture flowed into a flame holder even at a low equivalence ratio. Author

A93-19562
USING CONTRA-ROTATING ROTORS FOR DECREASING SIZES AND COMPONENT NUMBER IN SMALL GTE

B. A. PONOMAREV and IU. V. SOTSENKO (TsNII Aviatsionnogo Motorostroeniia, Moscow, Russia) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-414)

It is presently shown that the use of contrarotating (CR) high and low pressure spool rotors has an influence on gas turbine powerplant compressor parameters while substantially improving mass and dimensional requirements for a given output and fuel efficiency. Attention is given to the gasdynamic characteristics of the CR engine's hot section, as well as to that section's influence on other engine parameters; experimental data on the losses incurred within the rectilinear turbine cascades of highly curved profiles are presented. O.C.

A93-19563
AIRCRAFT TURBINE ENGINE NOX EMISSION LIMITS - STATUS AND TRENDS
D. W. BAHR (GE Aircraft Engines, Cincinnati, OH) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-415)

Within recent years, the NOx emissions of aircraft engines have received increased attention. More stringent limits on the NOx emissions of future subsonic civil aircraft engines are being considered. A 20 percent increase in the stringency of the existing ICAO standard has been proposed and, for the longer-term, the possibility of further increased stringency is being studied. For future supersonic civil aircraft engines, very stringent goals have been established. To meet these goals, combustor designs with ultralow NOx levels are required. Extensive efforts are, therefore, underway to develop low NOx combustors for use in future generations of both subsonic and supersonic aircraft engines. Author

A93-19564
ON-BOARD CONDITION MANAGEMENT FOR AIRCRAFT GAS TURBINES
G. W. GALLOPS, F. D. GASS, and M. H. KENNEDY (Pratt & Whitney Group, West Palm Beach, FL) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-416)

A revolutionary approach to gas turbine condition monitoring is made possible by the recent development of accurate real-time gas turbine performance models. This paper describes an approach for an integrated condition management system operating concurrently with the gas turbine control system for improved availability, safety and economy. This paper considers the system subject to the requirements and constraints of aircraft gas turbines. A system architecture is described based on a primary, gas path performance model with supplementary models representing the secondary air, fuel and lubrication systems and the rotor system dynamics. Measurement and processing requirements for the system are defined. Preflight, in-flight and postflight application and analysis by the gas turbine operator are discussed. Author

A93-19572
OPTIMIZATION OF A MULTISTAGE AXIAL COMPRESSOR IN A GAS TURBINE ENGINE SYSTEM
I. N. EGOROV (Air Force Engineering Academy, Moscow, Russia) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-424)

The work presents a procedure to determine the design parameters of multistage axial compressor (MAC) rows, the parameters optimum from the point of view to assure the best integrated indices of gas turbine engine (GTE) both at the design and off-design operation mode. Effectiveness of the proposed approach has been demonstrated with regards to solving the problems of optimum contouring by the radius of 7 rows of 4-stage fan included in a two-shaft turbofan. For the examples under consideration respective problems of nonlinear programming have been set whose dimensionality reached up to 63 of the design parameters of fan blade rows. It is shown, that the requirement to provide the best engine characteristics, integrated matching both GTE component parts (in our case these are compressor blade rows) and integrated characteristics of components included in an engine is of more importance than assuring the highest efficiency of separate components under consideration. Author

A93-19573
INVERSE DESIGN OF COMPRESSOR AND TURBINE BLADES AT TRANSONIC FLOW CONDITIONS
O. LEONARD (Mons, Faculte Polytechnique, Belgium) and R. A. VAN DEN BRAEMBUSSCHE (Von Karman Inst. for Fluid Dynamics, Rhode-St.-Genese, Belgium) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-430)

This paper describes the design of realistic blade shapes using an inverse method. Special attention is given to the geometrical and mechanical constraints imposed upon the blade. Examples presented in this paper illustrate how a better understanding of the theoretical relations between imposed velocity and resulting geometry can help satisfy the geometrical restrictions. Another method using a numerical procedure for finding a compromise between the target velocity distribution and geometrical restrictions is also proposed and illustrated by an example. A blade design procedure using an inviscid inverse method and a boundary layer calculation method is described and applied to the design of a shock free transonic compressor cascade. The iterative character of the procedure provides a blade shape control good enough to design sufficiently thick blades resulting in realistic geometries. The blade shape coordinates are given as a possible benchmark for inviscid or viscous two-dimensional methods. Author

A93-19580
DOUBLE MODE BEHAVIOUR OF BLADED DISK ASSEMBLIES IN THE RESONANCE FREQUENCY RANGE, VISUALIZED BY MEANS OF HOLOGRAPHIC INTERFEROMETRY
H. STETTER and R. KELLERER (Stuttgart Univ., Germany) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-438)

The vibration behavior of tuned and detuned systems in the frequency range near resonance of bladed disk assemblies is presented. Test simulation of defined order excitation is conducted with piezoelectric ceramics. The results of experimental studies with holographic interferometry and with strain gauges are compared with the results of an analytical model. R.E.P.

A93-20140#
EXPERIMENTAL INVESTIGATION OF EXHAUST SYSTEM MIXERS FOR A HIGH BYPASS TURBOFAN ENGINE
MOHAMED A. ABOLFADL and ARUN K. SEHRA (Textron Lycoming, Stratford, CT) Jan. 1993 17 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0022) Copyright

An experimental investigation was carried out to estimate the influence of geometric parameters on the performance of forced exhaust mixers for high bypass turbofan engines. A 30 percent scale model of a mixer designed for LF500 Series engines was used for this experimental study. Mixer geometric variables included lobe number, cutback, scalloping and mixing duct length. Mixing effectiveness, gross thrust coefficient and pressure loss were determined from measured thrust and nozzle exit total pressure and temperature surveys. Data were also obtained for a separated flow engine configuration and for a confluent (free) mixer configuration. The latter was used as a reference condition. Results from this study provide a data base for optimizing the design of turbofan forced mixer-exhaust systems. Author

A93-20280*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

AN EFFICIENT CONSTRAINT TO ACCOUNT FOR MISTUNING EFFECTS IN THE OPTIMAL DESIGN OF ENGINE ROTORS

DURBHA V. MURTHY (Toledo Univ.; NASA, Lewis Research Center, Cleveland, OH), CHRISTOPHE PIERRE, and GISLI OTTARSSON (Michigan Univ., Ann Arbor) Sep. 1992 7 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 refs

(AIAA PAPER 92-4711) Copyright

Blade-to-blade differences in structural properties, unavoidable in practice due to manufacturing tolerances, can have significant influence on the vibratory response of engine rotor blade. Accounting for these differences, also known as mistuning, in design and in optimization procedures is generally not possible. This note presents an easily calculated constraint that can be used in design and optimization procedures to control the sensitivity of final designs to mistuning. Author

A93-20319*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

STRUCTURAL TAILORING OF AIRCRAFT ENGINE BLADE SUBJECT TO ICE IMPACT CONSTRAINTS

E. S. REDDY, G. H. ABUMERI (Sverdrup Technology, Inc., Brook Park, OH), P. L. N. MURTHY, and C. C. CHAMIS (NASA, Lewis Research Center, Cleveland, OH) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 197-206. refs

(AIAA PAPER 92-4710) Copyright

In this paper, results are presented for the minimum weight design of SR2 unswept blade made of (Titanium/Graphite-Epoxy/Titanium)s fiber composite. The blade which is rotating at high RPM is subject to ice impact. The root chord length, blade thicknesses at five stations, and graphite-epoxy ply orientation are chosen as design variables. The design constraints are placed on the behavior variables: leading edge strain and root damage parameter due to ice impact, maximum post-impact bending stress at the root due to rotation, first three natural frequencies and resonance margin after impact. The method of feasible directions is employed to solve the inequality constrained minimization problem. The effect of ice speed and the ice impact location on the final design are discussed. Author

A93-20320* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

APPLE - AN AEROELASTIC ANALYSIS SYSTEM FOR TURBOMACHINES AND PROPFANS

T. S. R. REDDY, MILIND A. BAKHLE, R. SRIVASTAVA (Toledo Univ., OH), and ORAL MEHMED (NASA, Lewis Research Center, Cleveland, OH) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 207-225. refs

(Contract NAG3-1137; NAG3-1234; NAG3-1230)

(AIAA PAPER 92-4712) Copyright

This paper reviews aeroelastic analysis methods for propulsion elements (advanced propellers, compressors and turbines) being developed and used at NASA Lewis Research Center. These aeroelastic models include both structural and aerodynamic components. The structural models include the typical section model, the beam model with and without disk flexibility, and the finite element blade model with plate bending elements. The aerodynamic models are based on the solution of equations ranging from the two-dimensional linear potential equation for a cascade to the three-dimensional Euler equations for multi-blade configurations. Typical results are presented for each aeroelastic model. Suggestions for further research are indicated. All the available aeroelastic models and analysis methods are being incorporated into a unified computer program named APPLE (Aeroelasticity Program for Propulsion at LEwis). Author

A93-20321#

LIFE CYCLE ASSESSMENT OF AN IMPINGEMENT-COOLED GAS TURBINE BLADE

DAVID GREENBLAT, TREVOR J. KIRSTEN, PAOLO SENATORE, WILLEN J. LOUW, and MANFRED O. DEDEKIND (South African Council for Scientific and Industrial Research, Pretoria, South Africa) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 226-233. refs

(AIAA PAPER 92-4716) Copyright

This paper demonstrates a method for predicting the life of gas turbine hot section components which are subjected to larger thermo-mechanical loads during engine operating cycles. The technique makes use of an aerothermodynamic component incorporating measured engine data, a mean-line performance code, computational fluid dynamics and empirical correlations, and a structural finite element component. Results of the fluid flow computations were used as boundary conditions for the structural blade life analysis which considered the combined effect of fatigue and creep loading. This fluid-structure configuration was designed to conduct parametric studies of component upgrades, cooling modifications, etc. Specifically the effect of turbulence level variation as a result of combustor modification on an impingement cooled stator blade was investigated. It was ascertained that an increase from 4 to 12 percent in turbulence level resulted in a 10 percent decrease in blade life. Author

A93-21114*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

EFFECTS OF COMPRESSION AND EXPANSION RAMP FUEL INJECTOR CONFIGURATION ON SCRAMJET COMBUSTION AND HEAT TRANSFER

SCOTT D. STOUFFER (Virginia Polytechnic Inst. and State Univ., Blacksburg), N. R. BAKER (Lockheed Engineering and Sciences Co., Hampton, VA), D. P. CAPRIOTTI (Analytical Services and Materials, Inc., Hampton, VA), and G. B. NORTHAM (NASA, Langley Research Center, Hampton, VA) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(AIAA PAPER 93-0609) Copyright

A scramjet combustor with four wall-ramp injectors containing Mach-1.7 fuel jets in the base of the ramps was investigated experimentally. During the test program, two swept ramp injector designs were evaluated. One swept-ramp model had 10-deg compression-ramps and the other had 10-deg expansion cavities between flush wall ramps. The scramjet combustor model was instrumented with pressure taps and heat-flux gages. The pressure measurements indicated that both injector configurations were effective in promoting mixing and combustion. Autoignition occurred for the compression-ramp injectors, and the fuel began to burn immediately downstream of the injectors. In tests of the expansion ramps, a pilot was required to ignite the fuel, and the fuel did not burn for a distance of at least two gaps downstream of the injectors. Once initiated, combustion was rapid in this configuration. Heat transfer measurements showed that the heat flux differed greatly both across the width of the combustor and along the length of the combustor. Author

A93-21118*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

EVALUATION OF SCRAMJET NOZZLE CONFIGURATIONS AND FILM COOLING FOR REDUCTION OF WALL HEATING

N. R. BAKER (Lockheed Engineering and Sciences Co., Hampton, VA), G. B. NORTHAM (NASA, Langley Research Center, Hampton, VA), S. D. STOUFFER (Virginia Polytechnic Inst. and State Univ., Blacksburg), and D. P. CAPRIOTTI (Analytical Services and Materials, Inc., Hampton, VA) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993

refs
(AIAA PAPER 93-0744) Copyright

Experiments on relaminarization, or reverse transition of turbulent flow, have been conducted with a scramjet combustor and nozzle model. The Mach-2.7 direct-connect scramjet combustor employed swept-ramp fuel injectors, and the entering flow simulated Mach-6 to Mach-7 flight conditions. Tests were also conducted without combustor fuel to produce a higher nozzle entrance Mach number and lower pressures. Additional tests were conducted to evaluate the effectiveness of film cooling on the cowl region. At each test condition studied, the entrance radius had no significant effect on the measured downstream wall heating rates. Analysis of the data when fuel was injected into the combustor shows good agreement with turbulent theory; for the tests without fuel injection and combustion, the data downstream of the nozzle entrance radius are intermediate to the calculated turbulent and laminar solutions. Results of film-cooling tests, conducted with both hydrogen and nitrogen injectants, showed that, per unit mass, the hydrogen was approximately three to four times more effective than nitrogen in reducing the downstream wall heating rates. Author

A93-21667* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

SCRAMJET FUEL-AIR MIXING ESTABLISHMENT IN A PULSE FACILITY

R. C. ROGERS and ELIZABETH H. WEIDNER (NASA, Langley Research Center, Hampton, VA) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 127-133. Previously cited in issue 06, p. 809, Accession no. A91-19193 refs
Copyright

A93-21668

ROLE OF HYDROGEN/AIR CHEMISTRY IN NOZZLE PERFORMANCE FOR A HYPERSONIC PROPULSION SYSTEM

J. J. SANGIOVANNI, T. J. BARBER (United Technologies Research Center, East Hartford, CT), and S. A. SYED (Pratt & Whitney Group, West Palm Beach, FL) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 134-138. Previously cited in issue 17, p. 2651, Accession no. A90-40637 refs
Copyright

A93-21670

EFFECTS OF INJECTOR GEOMETRY ON SCRAMJET COMBUSTOR PERFORMANCE

NOBUO CHINZEI, TOMOYUKI KOMURO, KENJI KUDOU, ATSUO MURAKAMI, KOUICHIRO TANI, GORO MASUYA, and YOSHIO WAKAMATSU (National Aerospace Lab., Miyagi, Japan) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 146-152. Previously cited in issue 24, p. 4210, Accession no. A91-56232 refs
Copyright

A93-21671

AEROTHERMODYNAMIC ANALYSIS OF COMBINED-CYCLE PROPULSION SYSTEMS

A. R. GANJI, M. KHADEM, and S. M. H. KHANDANI (Berkeley Applied Science and Engineering, Inc., San Francisco, CA) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 153-155. Abridged. Previously cited in issue 08, p. 1110, Accession no. A90-22263 Research supported by USAF refs
Copyright

A93-21792

ROBUST DIGITAL CONTROL OF A HIGH-PERFORMANCE ENGINE

UBAID M. AL-SAGGAF (King Fahad Univ. of Petroleum and Minerals, Dhahran, Saudi Arabia) Dynamics and Control (ISSN 0925-4668) vol. 2, no. 4 Oct. 1992 p. 363-383. refs
Copyright

The design of a robust digital multivariable feedback control system for the F-100 turbofan jet engine is considered. The control system design problem is posed, and conditions for satisfying performance specifications and stability robustness are stated. The discrete LQG/LTR methodology is used to design a compensator that meets the stated specifications. New results for multi-input LQR loop shaping are derived. To get a reasonably low-order compensator, frequency-weighted reduced-order models are exploited, with the reduction error treated as an uncertainty. Author

A93-22325#

TEST RESULTS ON AIR TURBO RAMJET FOR A FUTURESPACE PLANE

NOBUHIRO TANATSUGU, YOSHIHIRO NARUO (Inst. of Space and Astronautical Science, Sagamihara, Japan), and ITARU ROKUTANDA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tanashi, Japan) Dec. 1992 11 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5054) Copyright

The analysis of the air-turbo ramjet (ATR) engine to power the TSTO space plane and the test results of the ATR at sea level static conditions are presented. Attention is given to ATR engine design criteria, performance characteristics and the turbomachinery mechanism. 30 test runs for a total operational time of 1190 seconds have been conducted between 1990 and 1992. R.E.P.

A93-22368#

DATA ANALYSIS OF THE PARAMETRIC SCRAMJET COMBUSTOR EXPERIMENTS CONDUCTED IN THE CALSPAN 96 INCH SHOCK TUNNEL - 4TH ENTRY

O. F. RIZKALLA and R. C. ORTH (General Applied Science Labs., Inc., Ronkonkoma, NY) Dec. 1992 12 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5098) Copyright

Semidirect connect tests aimed at building a database of scramjet combustor data at Mach 10 flight enthalpy were performed for various fuel injector concepts and CFD validation. The GASL/Calspan Fourth Entry Technology Maturation data set is analyzed to determine the relative combustion efficiency and combustor performance. The analyses are based on a fully mixed, equilibrium chemistry cycle code and a quasi-1D (three-stream), finite rate mixing and chemistry analysis. It is concluded that overall performance for the 90 deg hole injectors is the poorest due to relatively large flow losses associated with separation and excessive turbulence generation. The calculated value of the combustor effectiveness parameter is about 0.1. However, the combustion efficiency is found to be close to 100 percent based on the high fuel penetration obtained with normal injection and the the large pressure rise. O.G.

A93-22372#

STUDY ON STEADY AND UNSTEADY UNSTART PHENOMENA DUE TO COMPOUND CHOKING AND/OR FLUCTUATIONS IN COMBUSTOR OF SCRAMJET ENGINES

TETSUYA SATO (Inst. of Space and Astronautical Science, Sagamihara, Japan) and SHOJIRO KAJI (Tokyo Univ., Japan) Dec. 1992 12 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5102) Copyright

Unstart phenomena due to compound choking and thermal choking of airframe-integrated scramjet engine inlets were investigated experimentally and numerically. The compound choking is a phenomenon caused by interaction between the main flow and the forebody boundary layer flow ingested into engines. The numerical analysis was performed by using a one-dimensional two-stream-tube model and a quasi-three dimensional MacCormack differential model. The results of both analyses coincide qualitatively, and it is shown that the boundary layer flow spreads and pushes out the main flow in engine inlets, and that engines designed assuming a uniform inlet flow can be made unstart easily because of the existence of a low flow speed region like a boundary

layer. When side walls of engines sweep backward, the transition from start to unstart is rather continuous and the inlet performance at unstart conditions is not so badly deteriorated as the performance of inlets without sweep. Experiment is conducted using Mach 3 blowdown tunnel for research on the steady and transient conditions. Author

A93-22505* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE EFFECT OF ENTRANCE RADIUS AND FILM INJECTION ON WALL HEATING IN SCRAMJET NOZZLES
N. R. BAKER (Lockheed Engineering and Sciences Co., Hampton, VA), G. B. NORTHAM (NASA, Langley Research Center, Hampton, VA), D. P. CAPRIOTTI (Analytical Services and Materials, Inc., Hampton, VA), and S. D. STOUFFER (Virginia Polytechnic Inst. and State Univ., Blacksburg) Oct. 1992 13 p. JANNAF, Combustion Meeting, 29th, Hampton, VA, Oct. 19-23, 1992, Paper refs

An experimental study has been performed with a scramjet combustor and nozzle model to determine the effect of nozzle radii on relaminarization, and the effectiveness of film injection in reducing wall heat flux. The nozzle model was installed downstream of a swept-ramp scramjet combustor model, operated at Mach 2.7 with vitiated air, simulating Mach 6-7 flight enthalpies. Results from tests conducted with three nozzle radii, varying in curvature from a sharp Prandtl-Meyer expansion to a radius of two scramjet combustor exit heights, showed little or no effect on the downstream wall heat flux, which is not in agreement with both subsonic and supersonic relaminarization correlations in the available literature. In contrast, film injection upstream of all three radii produced reductions of 70 percent in the entire nozzle model heating rate, for the nominal film-to-free stream pressure matched condition. Results from film injection, with and without pressure gradient, but without wall curvature, show that the gradients appear to stabilize the film, with the resulting reductions in wall heat transfer rates apparent far downstream of the point of injection. Author

A93-22566#
SOME ISSUES CONCERNING ACTIVE CONTROL OF COMBUSTION INSTABILITY IN A RAMJET
SURESH MENON (Georgia Inst. of Technology, Atlanta) and VIGOR YANG (Pennsylvania State Univ., University Park) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract N00014-92-J-4030)
(AIAA PAPER 93-0116) Copyright

Active control of combustion instability in a ramjet has been numerically investigated using a large-eddy simulation technique. Various types of secondary fuel injection controllers have been investigated. The results of the study show that, in some cases, even when the amplitude of instability frequency is reduced, additional new frequencies can be excited which are not controlled. This phenomenon has been observed in the experiments, and has led to investigation of advanced adaptive controllers that employ neural net algorithms. Numerically, such controllers are computationally very expensive to train and therefore an alternate approach is sought. The approach proposed here employs a theoretical model for the dynamic behavior of nonlinear oscillations with distributed feedback actions. The theoretical model is used to analyse the simulation data (without control) and an optimization procedure is used to establish a criteria for selecting controller gains in terms of time-delays and locations of sensors and actuators. The theoretical analysis show that the limit cycle behavior of the LES-computed pressure oscillation during combustion instability can be reproduced quite well and further, that the theoretically devised controller can successfully suppress the amplitude of the oscillation. This demonstration provides the basis for the next step, which is to implement the theoretical model in the numerical simulation code to develop an adaptive secondary fuel injection controller that will automatically produce an optimum control response to the growth of the pressure oscillations. Author

A93-22568#
DEVELOPMENT OF AN OPTICAL SENSOR FOR ACTIVE CONTROL OF A GAS TURBINE COMBUSTOR
L. CHEN, V. G. MCDONELL, and G. S. SAMUELSEN (California Univ., Irvine) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Parker-Hannifin Corp refs
(AIAA PAPER 93-0118) Copyright

Closed-loop feedback control of a gas turbine combustor provides an opportunity to tailor the combustion performance in real time. In principle, this can be used to mitigate the production of pollutants and to reduce the combustor length. For this approach to be successful, sensors must be developed which provide consistent and relevant information. This paper describes the development of a reliable and stable optical sensor with high frequency response for combustion efficiency. Many candidates were evaluated. A CO2 radiometer made of PbSe has proven most useful. Calibration of the radiometer is conducted in a practical combustion environment using a computer code developed to calculate the radiation intensity that the sensor receives. A comparison of the radiometer signal with measured combustion efficiency is obtained. Author

A93-22660#
THREE-DIMENSIONAL NOX MODELING FOR RICH/LEAN COMBUSTOR
N. K. RIZK and H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) Jan. 1993 15 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0251) Copyright

An NOx model for rich/quench/lean (RQL) combustor is developed using detailed kinetic scheme calculation. The combustor modeling was based on the simulation of the RQL combustor by a number of reactors representing various combustion zones. NOx expressions are formulated in terms of a reaction temperature, a system pressure, an equivalence ratio, and residence time in each zone. The analysis showed that favorable conditions for NOx formation extended beyond the quench mixer section. This called for improved mixer design to achieve more rapid and uniform mixing of rich zone gases with the quench air. A hybrid model based on the analytical capabilities of the 3D code in conjunction with the developed NOx model is formulated. The NOx concentrations calculated by the hybrid model identified two main regions responsible for most of the NOx formed in the combustor. The overall NOx emission calculated for four different test points agreed well with the measurements. O.G.

A93-23041*# National Aeronautics and Space Administration, Washington, DC.
ISOLATOR-COMBUSTOR INTERACTION IN A DUAL-MODE SCRAMJET ENGINE
DAVID T. PRATT (Washington Univ., Seattle) and WILLIAM H. HEISER (Tennessee Univ., Tullahoma) Jan. 1993 16 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by National Aerospace Plane Joint Program Office and USAF refs
(AIAA PAPER 93-0358) Copyright

A constant-area diffuser, or 'isolator', is required in both the ramjet and scramjet operating regimes of a dual-mode engine configuration in order to prevent unstarts due to pressure feedback from the combustor. Because the nature of the combustor-isolator interaction is different in the two operational modes, however, attention is presently given to the use of thermal vs kinetic energy coordinates for these interaction processes' visualization. The results of the analysis thus conducted indicate that the isolator requires severe flow separation at combustor entry, and that its entropy-generating characteristics are more severe than an equivalent oblique shock. A constant-area diffuser is only marginally able to contain the equivalent normal shock required for subsonic combustor entry. O.C.

A93-23246# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
OPTIMIZATION OF CIRCULAR ORIFICE JETS MIXING INTO A HEATED CROSSFLOW IN A CYLINDRICAL DUCT
J. T. KROLL, W. A. SOWA, G. S. SAMUELSEN (California Univ., Irvine), and J. D. HOLDEMAN (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 18 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15359 refs
(Contract NAG3-1110; RTOP 505-68-10)
(AIAA PAPER 93-0249) Copyright

To examine the mixing characteristics of circular jets in an axisymmetric can geometry, temperature measurements were obtained downstream of a row of cold jet injected into a heated cross stream. The objective was to obtain uniform mixing within one duct radius downstream of the leading edge of the jet orifices. An area weighted standard deviation of the mixture fraction was used to help quantify the degree of mixedness at a given plane. Non-reacting experiments were conducted to determine the influence of the number of jets on the mixedness in a cylindrical configuration. Results show that the number of orifices significantly impacts the mixing characteristics of jets injected from round hole orifices in a can geometry. Optimum mixing occurs when the mean jet trajectory aligns with the radius which divides the cross sectional area of the can into two equal parts at one mixer radius downstream of the leading edge of the orifice. The optimum number of holes at momentum-flux ratios of 25 and 52 is 10 and 15 respectively.
Author

A93-23324# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ACOUSTIC MODE MEASUREMENTS IN THE INLET OF A MODEL TURBOFAN USING A CONTINUOUSLY ROTATING RAKE - DATA COLLECTION/ANALYSIS TECHNIQUES
DAVID G. HALL (Sverdrup Technology, Inc., Brook Park; NASA, Lewis Research Center, Cleveland, OH), LAURENCE HEIDELBERG, and KEVIN KONNO (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15403 refs
(Contract RTOP 535-03-10)
(AIAA PAPER 93-0599) Copyright

The rotating microphone measurement technique and data analysis procedures are documented which are used to determine circumferential and radial acoustic mode content in the inlet of the Advanced Ducted Propeller (ADP) model. Circumferential acoustic mode levels were measured at a series of radial locations using the Doppler frequency shift produced by a rotating inlet microphone probe. Radial mode content was then computed using a least squares curve fit with the measured radial distribution for each circumferential mode. The rotating microphone technique is superior to fixed-probe techniques because it results in minimal interference with the acoustic modes generated by rotor-stator interaction. This effort represents the first experimental implementation of a measuring technique developed by T. G. Sofrin. Testing was performed in the NASA Lewis Low Speed Anechoic Wind Tunnel at a simulated takeoff condition of Mach 0.2. The design is included of the data analysis software and the performance of the rotating rake apparatus. The effect of experiment errors is also discussed.
Author

A93-23331#
DESIGN OF EXHAUST NOZZLES USING GA OPTIMIZED NEURAL NETWORKS
KEVIN W. WHITAKER (Alabama Univ., Tuscaloosa) and RAVI K. PRASANTH (Purdue Univ., West Lafayette, IN) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0410) Copyright

A study is performed into using a genetic algorithm (GA) optimized neural network in an attempt to derive, in real-time, 2D minimum length and thrust vectoring nozzle contours. Nozzle force angles up to 20 degrees are obtained within an average error of 0.0914 degrees. It is concluded that neural networks provide a viable, real-time alternative for designing exhaust nozzles. R.E.P.

A93-23384# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN IMPROVED NUMERICAL MODEL FOR WAVE ROTOR DESIGN AND ANALYSIS
DANIEL E. PAXSON (NASA, Lewis Research Center, Cleveland, OH) and JACK WILSON (Sverdrup Technology, Inc., Cleveland, OH) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-12418 refs
(Contract RTOP 505-62-10)
(AIAA PAPER 93-0482) Copyright

A numerical model has been developed which can predict both the unsteady flows within a wave rotor and the steady averaged flows in the ports. The model is based on the assumptions of one-dimensional, unsteady, and perfect gas flow. Besides the dominant wave behavior, it is also capable of predicting the effects of finite tube opening time, leakage from the tube ends, and viscosity. The relative simplicity of the model makes it useful for design, optimization, and analysis of wave rotor cycles for any application. This paper discusses some details of the model and presents comparisons between the model and two laboratory wave rotor experiments.
Author

N93-15979# Naval Postgraduate School, Monterey, CA.
STATIC PRESSURE MEASUREMENTS OF THE SHOCK-BOUNDARY LAYER INTERACTION IN A SIMULATED FAN PASSAGE M.S. Thesis
WILLIAM L. GOLDEN, JR. Mar. 1992 136 p
(AD-A256724) Avail: CASI HC A07/MF A02

Two-dimensional experimental and numerical simulations of a transonic fan blade passage (M = 1.4) were conducted to provide baseline data for the study of the effects of vortex generating devices on shock-boundary layer interaction. A back pressure valve was designed for a transonic cascade blowdown wind tunnel, the test section was instrumented, and time-averaged static pressure distributions across the shock-boundary layer interaction were obtained. A numerical Navier-Stokes solution to the flow was also found. Sensitive and repeatable control of the cascade pressure ratio was demonstrated and the flow was shown to be reasonably two-dimensional across the span. GRA

N93-16080# Texas Univ., Austin. Turbulence and Turbine Cooling Research Lab.
HYDRODYNAMIC EFFECTS ON HEAT TRANSFER FOR FILM-COOLED TURBINE BLADES Final Report, Sep. 1988 - 30 Apr. 1992
DAVID G. BOGARD, KAREN A. THOLE, and MICHAEL E. CRAWFORD May 1992 115 p
(Contract F33615-88-C-2830)
(AD-A257291; WL-TR-92-2035) Avail: CASI HC A06/MF A02

The objectives were to develop a technique for generating very high freestream turbulence levels and to determine resulting effects on turbulent boundary layer and film cooling flows. Also, included was the development of a simultaneous temperature/velocity measurement technique. All of these objectives were accomplished as described below; however, film cooling flows were studied only for minimal freestream turbulence levels. Several turbulence generating devices were studied to determine the maximum turbulence levels. Tests indicated that high velocity jets in cross-flow generated turbulence levels, Tu, which ranged from Tu = 20 to 11 pct. over a 0.65 m distance. The turbulence integral length scales for this flow were on the order of boundary layer thickness. High freestream turbulence levels caused significant increases in surface heat flux. Various correlations for freestream turbulence affects on surface heat flux were evaluated. None of these correlations were adequate; however, with slight modifications two of the correlations reasonably collapsed the data. Thermal field measurements of simulated film

cooling flows with a minimal freestream turbulence level indicated that the jet detachment/reattachment scaled with the momentum flux ratio. GRA

N93-16705*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

ACOUSTIC MODE MEASUREMENTS IN THE INLET OF A MODEL TURBOFAN USING A CONTINUOUSLY ROTATING RAKE

LAURENCE J. HEIDELBERG and DAVID G. HALL (Sverdrup Technology, Inc., Brook Park, OH.) Dec. 1992 31 p Presented at the 31st Aerospace Sciences Meeting, Reno, NV, 11-14 Jan. 1993; sponsored by AIAA
(Contract RTOP 535-03-10)
(NASA-TM-105989; E-7476; NAS 1.15:105989; AIAA PAPER 93-0598) Avail: CASI HC A03/MF A01

Comprehensive measurements of the spinning acoustic mode structure in the inlet of the Advanced Ducted Propeller (ADP) have been completed. These measurements were taken using a unique and previously untried method which was first proposed by T.G. Sofrin. A continuously rotating microphone system was employed. The ADP model was designed and built by Pratt & Whitney and tested in the NASA Lewis 9- by 15-foot Anechoic Wind Tunnel. Three inlet configurations were tested with cut-on and cutoff stator vane sets. The cutoff stator was designed to suppress all modes at the blade passing frequency. Rotating rake measurements indicate that several extraneous circumferential modes were active. The mode orders suggest that their source was an interaction between the rotor and small interruptions in the casing tip treatment. The cut-on stator produced the expected circumferential modes plus higher levels of the unexpected modes seen with the cutoff stator. Author

N93-16715*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

TAKEOFF/APPROACH NOISE FOR A MODEL COUNTERROTATION PROPELLER WITH A FORWARD-SWEPT UPSTREAM ROTOR

RICHARD P. WOODWARD, DAVID G. HALL (Sverdrup Technology, Inc., Brook Park, OH.), GARY G. PODBOY, and ROBERT J. JERACKI Jan. 1993 23 p Presented at the 31st AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, 11-14 Jan. 1993; sponsored by AIAA
(Contract RTOP 535-03-10)
(NASA-TM-105979; E-7479; NAS 1.15:105979; AIAA PAPER 93-0596) Avail: CASI HC A03/MF A01

A scale model of a counterrotating propeller with forward-swept blades in the forward rotor and aft-swept blades in the aft rotor (designated F39/A31) has been tested in the NASA Lewis 9- by 15-Foot Anechoic Wind Tunnel. This paper presents aeroacoustic results at a takeoff/approach condition of Mach 0.20. Laser Doppler velocimeter results taken in a plane between the two rotors are also included to quantify the interaction flow field. The intention of the forward-swept design is to reduce the magnitude of the forward rotor tip vortex and/or wakes which impinge on the aft rotor, thus lowering the interaction tone levels. A reference model propeller (designated F31/A31), having aft-swept blades in both rotors, was also tested. Aeroelastic performance of the F39/A31 propeller was disappointing. The forward rotor tip region tended to untwist toward higher effective blade angles under load. The forward rotor also exhibited steady state blade flutter at speeds and loadings well below the design condition. The noise results, based on sideline acoustic data, show that the interaction tone levels were up to 8 dB higher with the forward-swept design compared to those for the reference propeller at similar operating conditions, with these tone level differences extending down to lower propeller speeds where flutter did not occur. These acoustic results are for a poorly-performing forward-swept propeller. It is quite possible that a properly-designed forward-swept propeller would exhibit substantial interaction tone level reductions. Author

N93-16941*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

A CRITICAL ANALYSIS OF THE ACCURACY OF SEVERAL NUMERICAL TECHNIQUES FOR COMBUSTION KINETIC RATE EQUATIONS

KRISHNAN RADHADRISHNAN Jan. 1993 62 p
(Contract RTOP 505-31-42)
(NASA-TP-3315; E-5861; NAS 1.60:3315) Avail: CASI HC A04/MF A01

A detailed analysis of the accuracy of several techniques recently developed for integrating stiff ordinary differential equations is presented. The techniques include two general-purpose codes EPISODE and LSODE developed for an arbitrary system of ordinary differential equations, and three specialized codes CHEMEQ, CREK1D, and GCKP4 developed specifically to solve chemical kinetic rate equations. The accuracy study is made by application of these codes to two practical combustion kinetics problems. Both problems describe adiabatic, homogeneous, gas-phase chemical reactions at constant pressure, and include all three combustion regimes: induction, heat release, and equilibration. To illustrate the error variation in the different combustion regimes the species are divided into three types (reactants, intermediates, and products), and error versus time plots are presented for each species type and the temperature. These plots show that CHEMEQ is the most accurate code during induction and early heat release. During late heat release and equilibration, however, the other codes are more accurate. A single global quantity, a mean integrated root-mean-square error, that measures the average error incurred in solving the complete problem is used to compare the accuracy of the codes. Among the codes examined, LSODE is the most accurate for solving chemical kinetics problems. It is also the most efficient code, in the sense that it requires the least computational work to attain a specified accuracy level. An important finding is that use of the algebraic enthalpy conservation equation to compute the temperature can be more accurate and efficient than integrating the temperature differential equation. Author

N93-17613# Centre National de la Recherche Scientifique, Paris (France). Ecole Centrale Paris.

COMBUSTION INSTABILITIES IN A SIDE-DUMP MODEL RAMJET COMBUSTOR

J. M. SAMANIEGO, B. YIP, T. POINSOT, and S. CANDEL *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 17 p Sep. 1992
Copyright Avail: CASI HC A03/MF A03

Combustion instabilities are often observed in coaxial and side-dump combustors and can be detrimental to their performance. This study is aimed at identifying the physical mechanisms underlying combustion instabilities in these geometries. Recent studies performed on side-dump geometries have focused on hydrodynamic instabilities under non-reacting conditions. The present work was conducted on a two-dimensional two-inlet side-dump combustor, fed with a premixture of air and propane in order to examine reacting flow instabilities. Results from a stable combustion regime are presented in order to provide a basis for comparison with a low-frequency instability mode (520 Hz) which occurs at other combustor operating conditions. The flowfield structure is investigated using high speed Schlieren visualization and conditional C2 imaging. Simultaneous pressure, inlet velocity, and global C2 emission measurements are used to investigate the nature of the instability. Different processes involved in the instability mode are identified such as the acoustics of the combustor, the oscillatory motion of the jets underlying periodic jet-on-jet impingement and a complex behavior of the reaction zones. Furthermore, by obtaining an experimental local Rayleigh index distribution, it has been possible to identify the driving mechanisms of this instability. Author

N93-17622# Centre d'Etudes et de Recherches, Toulouse (France).
PREDICTION OF THE PERFORMANCES IN COMBUSTION OF RAMJETS AND STATO-ROCKETS BY ISOTHERMAL EXPERIMENTS AND MODELING [PREDICTION DES PERFORMANCES EN COMBUSTION DE STATO-REACTEURS ET STATO-FUSEES PAR EXPERIMENTATIONS ISOTHERMES ET MODELISATIONS]
P. HEBRARD, G. LAVERGNE, A. TORGUE, F. BISMES, and G. HEID *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 9 p Sep. 1992 In FRENCH
Copyright Avail: CASI HC A02/MF A03

This publication presents a semi-empirical approach aimed at studying the internal aerodynamic characteristics of combustion chambers and using this information to predict the performance of various ramjet and strato-rocket combustion chambers. The step suggested, which appeared to be completely operational for numerous treated cases, is based on the joint use of experiments, carried out in isothermal simulated conditions, and of a one dimensional modeling using the concept of elementary jet engines. The experiments are undertaken on hydraulic test rigs or aerodynamic installations using reduced scale models. Conventional techniques of visualization then make it possible to reach the first qualitative description of the flow. Those are supplemented by a certain number of measurements resulting from image processing carried out on preceding visualizations. This quantitative information consisting of the distribution of flow, residence time, and concentration, is then translated into the form of input data for computer code. This calculation, carried out the second time, can use complex chemical kinetics to describe combustion and thus makes it possible to predict, with a good degree of accuracy, the total performance of the chamber (stability limits, combustion output as a function of operating characteristics, etc.,). The interest of such a step during the preliminary draft stage was shown for a significant number of chambers by comparing the results obtained in combustion with those resulting from calculation. Transl. by FLS

N93-17686# Naval Postgraduate School, Monterey, CA.
PRELIMINARY ANALYSIS OF THE J-52 AIRCRAFT ENGINE COMPONENT IMPROVEMENT PROGRAM M.S. Thesis
RANDALL S. BUTLER 1 Sep. 1992 104 p
(AD-A257640) Avail: CASI HC A06/MF A02

Increasing budgetary constraints have required program managers within the Naval Air Systems Command to justify their programs as never before. This thesis presents a preliminary analysis of the J-52 aircraft engine Component Improvement Program (CIP). The objectives of the research were to scrutinize the association of the CIP with promised improvements and benefits pertaining to the J-52 engine and to determine the obstacles that existing data bases present when an attempt is made to calculate the success or failure of a component modification. A history of the J-52 engine is provided along with a broad look at various engine performance parameter trends for the period 1984-1990. Ten Engineering Change Proposals (ECP's) are then examined. Analysis shows that while only one of the ten ECP related fixes can be directly correlated to a tangible increase in engine performance, the overall trends have been promising with regard to improving engine maintainability, reliability, and safety related factors. GRA

N93-17695# Naval Postgraduate School, Monterey, CA.
ANALYSIS OF CONSOLIDATION OF INTERMEDIATE LEVEL MAINTENANCE FOR ATLANTIC FLEET T700-GE-401 ENGINES M.S. Thesis
JEFFREY S. COOK Jun. 1992 128 p
(AD-A257754) Avail: CASI HC A07/MF A02

This thesis is an analysis of consolidation of duplicate capabilities for intermediate level maintenance of T700-GE-401 turboshaft engines belonging to Naval Air Force, Atlantic Fleet. The down-sizing of the military in the next decade and the resulting budget constrained reality will force the Navy to adopt innovative measures to save costs. One of the methods by which costs can be reduced is by combining the maintenance functions of activities with duplicated capabilities into one facility, as is proposed for the maintenance facilities for this engine. To test the feasibility of the consolidation concept, the thesis uses simulation to model an Aircraft Intermediate Maintenance Department (AIMD) operating as a consolidated T700 maintenance facility under a worst-case scenario. Based on the simulation results, the thesis concludes that the proposed consolidation is a viable concept. The thesis also uses life cycle cost analysis to quantify some of the cost savings resulting from the consolidation. Specific recommendations are then made regarding implementation of the consolidation concept. GRA

N93-17740# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
TURBOMACHINERY AND POTENTIAL COMPUTATIONS [TURBOMACHINES ET CALCULATEURS DE POTENTIEL]
J. M. VIGUIER, R. KRAFFT, and J. P. MASCARELL 1991 18 p In FRENCH Presented at Journees de Printemps de la Societe Francaise de Metallurgie et de Materiaux Commission de Fatigue des Materiaux on 'Amorcage en Fatigue et Compteurs de Dommages', Paris, France, 28-29 May 1991
(DS-2026; ETN-93-93372) Copyright Avail: CASI HC A03/MF A01

A set of overhead projector graphics demonstrating means of calculating aerodynamic potential is presented. Calculation of lifetime and the thermodynamic, thermal mechanical damage, and remaining potential, of the jet engine, are considered. Calculation of potential is concluded to: avoid the risk of failure of vital parts; take into account the disparity between the real mission of each engine; optimize the maintenance logistics by real ageing knowledge; and reduce up keep costs through optimized maintenance. ESA

N93-17849# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Paris (France).
SNECMA M88 ENGINE DEVELOPMENT STATUS
J. C. CORDE 1991 5 p Presented at 35th International Gas Turbine and Aeroengine Congress and Exposition, Brussels, Belgium, 11-14 Jun. 1990 Previously announced in IAA as A91-23636 Repr. from Transactions of the ASME, v. 113, Jan. 1991 p 20-24
(ASME-90-GT-118; ETN-93-93377) Avail: CASI HC A01/MF A01

The historical origins of the SNECMA M88 engine development program are described and the general development planning until the production engine flight qualification at the end of 1995 is presented. The technical aspects of the program are emphasized. The main new technologies involved in the engine, the general arrangement, and the performance are described and the engine development status is fully presented (development philosophy, main component tests, and complete engine tests). ESA

N93-17851# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France). Combustion Dept.
TURBINE ENGINE COMBUSTOR DESIGN AT SNECMA
M. DESAULTY 1991 8 p Presented at 10th ISABE International Symposium on Air Breathing Engines, Nottingham, England, 1-6 Sep. 1991 Previously announced in IAA as A91-56108
(DS-2129; ETN-93-93389) Avail: CASI HC A02/MF A01

Research on the technologies and calculation methods needed to meet the performance, cost, and deadline requirements for future engines is described. It is suggested that attention should focus on structure and coding and injection techniques when designing combustors. The required performance is outlined, the combustor operation is explained, and technological research challenges to military and civil aircraft are addressed. Technological research addresses injection systems and new combustor structures (double annular combustor and variable geometry combustors). Calculation methods, particularly the two and three dimensional Navier-Stokes codes, which have improved flow understanding and thus enabled costs to be reduced and deadlines shortened for the development of new concepts, are discussed. ESA

N93-17882# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
THE TECHNOLOGICAL EVOLUTION OF HIGH THRUST TURBINE ENGINES
ROGER BOUILLET (Ecole Nationale Superieure d'Arts et Metiers, Paris, France) 1984 18 p In FRENCH Previously announced in IAA as A85-26017 Repr. from L'Aeronautique et L'Astronomique, v. 4, no. 107, 1984 p 29-46
(DS-1881; ETN-93-93383) Avail: CASI HC A03/MF A01

Because of design compromises, operational qualities expected from advanced turbine engines have lead to the introduction of typical formulae of engines. These formulae are discussed in the context of the complete engine and its major components (fans, compressor, combustors, turbines). The evolutions of the current technologies most likely to occur during the new decade are evaluated. The principle factors affecting the operational qualities of civil and military engines are reviewed: pollution, reliability/security, life duration/maintenance, type of engine. The integration of the different parts and the materials used are addressed. ESA

N93-18149# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry (France). Dept. Materiaux et Procedes.
FATIGUE OF TURBOENGINE DISCS
E. BACHELET and J.-Y. GUEDOU 5 May 1991 11 p In FRENCH Presented at INSTN Journees de Metallurgie, Jun. 1989 Repr. from Memoires et Etudes Scientifiques Revue de Metallurgie, Jun. 1991 p 369-379
(DS-2136; ETN-93-93387) Avail: CASI HC A03/MF A01

Mechanical fatigue in turboengines is addressed. This takes account of the fatigue in the case of compressors or turbine disks in their technical or even economical context. Methods performed to deal with them are reviewed. The main problems practitioners working in this field have to solve are presented. The expectations of clients in terms of performance, reliability and costs are addressed. The thermal and mechanical applications of the materials are discussed. Methods of determining the life duration of the parts are addressed. Developments in the metallurgical field are considered with particular attention given to short crack propagation. ESA

N93-18151# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Evry (France). Direction de la Qualite.
CONTROL OF IN-SERVICE DAMAGE: APPLICATION TO AIRCRAFT ENGINES [CONTROLE DE L'ENDOMMAGEMENT EN SERVICE: APPLICATION AUX MOTEURS D'AVION]
J. M. THERET 1991 20 p In FRENCH Presented at Journees de Printemps de la Societe Francaise de Metallurgie et de Materiaux Commission de Fatigue des Materiaux on Amorcage en Fatigue en Compteurs de Dommages, Paris, France, 28-29 May 1991
(DS-2027; ETN-93-93391) Avail: CASI HC A03/MF A01

Precautions taken in order to control engine damage, which are necessary if good safe engine performance is to be guaranteed, are addressed. The critical engine parts are those whose rupture could cause major damage to the aircraft. The control of damage takes several forms and each of these are discussed: design validation through studies of engine aging and life duration of the individual parts; the surveillance of engines through constant verification of selected parameters and through periodic controls in order to find sites of possible damage before real harm is caused; and the control of damage to decide whether the part is withdrawn or whether it undergoes further tests. Examples of nondestructive tests performed are given. ESA

N93-18578*# Pratt and Whitney Aircraft, East Hartford, CT. Commercial Engineering.
CREEP FATIGUE LIFE PREDICTION FOR ENGINE HOT SECTION MATERIALS (ISOTROPIC) Final Report, May 1987 - Feb. 1989
R. S. NELSON, G. W. LEVAN, and P. R. HARVEY Aug. 1992 109 p
(Contract NAS3-23288; RTOP 590-21-11)
(NASA-CR-189221; NAS 1.26:189221; PWA-5894) Avail: CASI HC A06/MF A02

This Final Report covers the activities completed under the optional program of the NASA HOST Contract, NAS3-23288. The initial effort of the optional program was report-in NASA CR189221, which consisted of high temperature strain controlled fatigue tests to study the effects of thermomechanical fatigue, multiaxial loading, reactive environments, and imposed stresses. The baseline alloy used in the tests included B1900+Hf (with or without coating) and wrought INCO 718. Tests conducted on B1900+Hf included environmental tests using various atmospheres (75 psig oxygen, purified argon, or block exposures) and specimen tests of wrought INCO 718 included tensile, creep, stress rupture, TMF, multiaxial, and mean stress tests. Results of these testings were used to calibrate a CDA model for INCO 718 alloy and to develop modifications or corrections to the CDA model to handle additional failure mechanisms. The Socie parameter was found to provide the best correlation for INCO multiaxial loading. Microstructural evaluations consisting of optical, Scanning Electron Microscopy (SEM), and Transmission Electron Microscopy (TEM) techniques, and surface replication techniques to determine crack initiation lives provided data which were used to develop life prediction models. Author

N93-18628# Universitaet der Bundeswehr Muenchen, Neubiberg (Germany). Fakultaet fuer Luft- und Raumfahrttechnik.
EXPERIMENTAL AND NUMERICAL EXAMINATIONS OF THE INFLUENCE OF INLET DISTORTION PERTURBATIONS ON THE WORKING BEHAVIOR OF TURBOFAN COMPRESSORS Ph.D. Thesis [EXPERIMENTELLE UND NUMERISCHE UNTERSUCHUNGEN ZUM EINFLUSS VON EINTRITTSDRALLSTOERUNGEN AUF DAS BETRIEBSVERHALTEN VON FLUGTRIEBWERKSVERDICHTERN]
WOLFRAM PAZUR 1991 180 p In GERMAN
(ETN-93-92733) Avail: CASI HC A09/MF A02

Examinations of a compressor integrated in a turbofan were carried out to consider the interaction effects between independent components. A test facility was built to study the behavior of the low pressure compressor of Larzac O4: a distortion generator that was designed with a delta wing to create simulated turbofan instabilities. The compressor inlet and exhaust temperatures were measured by means of thermocouples (Fe-Co, Ni-Cr-Ni). Two pressure probes were introduced through existing openings in the air intake to measure the total pressure. A numerical model was developed to describe stationary distortion perturbations through an axial compressor and the pressure losses and was extended to the nonstationary case. The results were compared with experimental data and a good estimation was found for isentropic efficiency and compression ratio. It is shown that a distortion perturbation induces changes in the characteristic line of the compressor but does not influence its dynamic characteristics. This phenomenon is experimentally proved and established by a power synthesis calculation. ESA

N93-18702*# General Motors Corp., Indianapolis, IN.
INVESTIGATION OF ADVANCED COUNTERROTATION BLADE CONFIGURATION CONCEPTS FOR HIGH SPEED TURBOPROP SYSTEMS. TASK 4: ADVANCED FAN SECTION AERODYNAMIC ANALYSIS COMPUTER PROGRAM USER'S MANUAL Report, Jul. 1991 - Jul. 1992
ANDREW J. CROOK and ROBERT A. DELANEY Nov. 1992 70 p
(Contract NAS3-25270)
(NASA-CR-187127; NAS 1.26:187127) Avail: CASI HC A04/MF A01

The computer program user's manual for the ADPACAPES (Advanced Ducted Propfan Analysis Code-Average Passage Engine Simulation) program is included. The objective of the computer program is development of a three-dimensional Euler/Navier-Stokes flow analysis for fan section/engine geometries containing multiple blade rows and multiple spanwise

flow splitters. An existing procedure developed by Dr. J. J. Adamczyk and associates at the NASA Lewis Research Center was modified to accept multiple spanwise splitter geometries and simulate engine core conditions. The numerical solution is based upon a finite volume technique with a four stage Runge-Kutta time marching procedure. Multiple blade row solutions are based upon the average-passage system of equations. The numerical solutions are performed on an H-type grid system, with meshes meeting the requirement of maintaining a common axisymmetric mesh for each blade row grid. The analysis was run on several geometry configurations ranging from one to five blade rows and from one to four radial flow splitters. The efficiency of the solution procedure was shown to be the same as the original analysis.
Author

N93-18997# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
DEVELOPMENT OF AN ENGINE/AIRFRAME PERFORMANCE MATCHING SCHEME FOR JET ENGINE RETROFIT M.S. Thesis
ALAN LACH Dec. 1992 156 p
(AD-A258822; AFIT/GAE/ENY/92D-19) Avail: CASI HC A08/MF A02

This investigation developed a procedure and new analysis tools for identifying retrofit engine designs for use in existing airframes. The goal was to find a replacement engine for the air-to-air fighter, AAF, developed in the textbook Aircraft Engine Design. This paper introduced the ideas of solution surfaces, constraint/thrust diagrams, quality measures and linear regression analysis for the engine design problem. It considered the application of the jet engine design software ACSYS, MISS, and ONX along with statistical analysis software, SAS. Modeling techniques and linear regression analysis were used to minimize iteration while searching a wide range of design variables. Improvements to the design point engine selection process were made through the development of quality measures for choosing appropriate values for bypass ratio and compressor pressure ratio. The analysis tools were assembled into a design scheme for engine retrofit which was then demonstrated with a two-variable and a six-variable design example. The result of the study determined a new baseline engine design for the AAF with increased thrust and decreased fuel consumption. This design process was developed for use by design students in the academic environment. GRA

N93-19093# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
CHARACTERIZATION OF STALL INCEPTION IN HIGH-SPEED SINGLE-STAGE COMPRESSORS M.S. Thesis
KEITH M. BOYER Dec. 1992 157 p
(AD-A258973; AFIT/GAE/ENY/92D-21) Avail: CASI HC A08/MF A02

Two single-stage, transonic compressor designs were tested under various undistorted operating conditions to characterize the process leading up to aerodynamic stall. The rig case was instrumented with eight high-response static pressure transducers equally spaced around the annulus for stall development detection. High-response measurements were low-pass filtered and both spatially and temporally analyzed using discrete Fourier techniques. At all speeds tested for both designs, stall inception was characterized by growth of a small amplitude rotating wave. The waves did not grow significantly until just prior to the instability, when exponential growth into fully-developed rotating stall occurred very rapidly, within 6-10 rotor revolutions. The amount of time the rotating waves could be detected prior to stall varied considerably with compressor operating condition and was largely dependent on the local slope of the compressor speedline characteristics. Stall warning times ranged from less than one-tenth of a second to more than two seconds for the same machine operated at different high speeds (above 60 percent design speed). The influence of compressibility effects are also discussed. GRA

N93-19326# Ishikawajima-Harima Heavy Industries Co. Ltd., Tokyo (Japan).
ROLE OF WIND TUNNEL TESTS AND CFD ANALYSIS FOR THE DEVELOPMENT OF AERO-ENGINES IN IHI [IHI KOUKUU ENJIN NI OKERU FUUDOU JIKKEN TO CFD]
ATSUSHIGE TANAKA *In* NAL, Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 337-344 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

When aeroengines are developed, several different types of wind tunnel tests are involved. For instance, one type of tunnel is required for fundamental tests of the cascades; a second is required for high altitude engine performance tests. Experimental models for these tests consist of real engine components or of close replicas. Certain effects may not be adequately addressed in wind tunnel tests, for example, the effects of high speed revolution, flow properties in unmeasurable regions, realistic boundary conditions. The twofold object of Computational Fluid Dynamics (CFD) for internal flows is to predict the performance of models before expensive wind tunnel tests are done and to provide information of the internal flow that is inaccessible to experiment measurement. CFD is already useful for improving designs or making new ones. As computers and CFD technology advance, CFD can expand from the role of prediction and design to that of a numerical wind tunnel. This paper shows how features of numerical wind tunnels parallel those of experimental wind tunnels. The paper also assesses future trends for the use of numerical wind tunnels. Author (NASDA)

N93-19356# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
INTEGRATED BLADE INSPECTION SYSTEM (IBIS) UPGRADE STUDY M.S. Thesis
TONY J. DELIBERATO, STEVEN W. PERKINS, STEVEN K. SAPLIN, JOHN G. SNYDER, and GREGORY J. TOUSSAINT Dec. 1992 294 p
(AD-A258912; AFIT/GSE/ENY/92D-03) Avail: CASI HC A13/MF A03

The purpose of this design study was to identify ways to improve the Integrated Blade Inspection System. The Air Force requires inspection of jet engine compressor and turbine blades to locate defects and prevent engine failure. The current inspection process uses fluorescent penetrant as an aid to identify cracked blades. A systems engineering design process was applied to evaluate the current inspection techniques and to develop alternative methods to satisfy the Air Force requirements. Three different inspection systems were developed and compared to the current process: manual, semi-automated, and fully automated inspection. This study made several noteworthy contributions: development of classification software to validate the neural network approach for accurate blade classification, demonstration of potential advantages of charge-coupled device cameras for data gathering, quantification of the cost of incorrectly classifying jet engine blades, examination of the value of a statistical quality control plan for the inspection process, and identification of a method using multiple images to extract additional features from cracks. The study demonstrates that the fully automated system could dramatically outperform the manual inspection process by improving the consistency of the inspection process and raising the quality of the blades returned to service. GRA

08

AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

A93-17721
THE SMART STRUCTURES TECHNOLOGY IN THE VIBRATION CONTROL OF HELICOPTER BLADES IN FORWARD FLIGHT
FRED NITZSCHE and ELMAR BREITBACH (DLR, Inst. fuer Aeroelastik, Goettingen, Germany) *In* European Conference on Smart Structures and Materials, 1st, Glasgow, United Kingdom, May 12-14, 1992, Proceedings Orsay, France/Bellingham, WA/Bristol, United Kingdom European Optical Society/Society of Photo-Optical Instrumentation Engineers/Institute of Physics 1992 p. 321-324. refs
Copyright
The performance of a single input, single output, individual blade control system, designed to attenuate the helicopter rotor vibration using piezoelectric crystals (PZT) embedded in the blade structure, is studied. The results indicate that an efficient control of the blade lower damped modes, which significantly contribute to the unpleasant vibration of helicopters, may be achieved with a 'smart' adaptive controller. Author

A93-18363
IMPROVING THE SERVICE CHARACTERISTICS OF AN AIRCRAFT THROUGH THE GYROSCOPIC DAMPING OF ITS STRUCTURE [ULUCHSHENIE EKSPLUATATSIONNYKH KHARAKTERISTIK SAMOLETA PUTEM GIROSKOPICHESKOGO VOZDEISTVIIA NA EGO KONSTRUKTSIIU]
O. I. GAINUTDINOV and A. N. PROKOP'EV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 51-54. In Russian. refs
Copyright
The gyroscopic damping of the aircraft structure in flight is examined as a method of protecting the on-board instrumentation and the crew against aeroelastic vibrations of the structure. An implementation of such gyroscopic damping system is described, and results of the use of the system on a hypothetical aircraft flying under conditions of atmospheric turbulence are discussed. V.L.

A93-18378
SOLUTION OF TRAJECTORY OPTIMIZATION METHODS USING THE PONTRIAGIN MAXIMUM PRINCIPLE [RESHENIE TRAEKTORNYKH OPTIMIZATSIONNYKH ZADACH DINAMIKI POLETA S ISPOL'ZOVANIEM PRINTSIPA MAKSIMUMA L.S. PONTRIAGINA]
D. M. SHAN'GIN and O. IA. IAKIMENKO *In* Problems in the aerodynamics and dynamics of flight vehicles in the light of K.E. Tsiolkovsky's ideas; Lectures Devoted to K.E. Tsiolkovsky's Ideas, 25th, Kaluga, Russia, Sept. 11-14, 1990, Transactions Moscow AN SSSR, Institut Istorii Estestvoznaniia i Tekhniki 1991 p. 10-13. In Russian. refs
Copyright
Two trajectory optimization problems are considered, one of which is a regular optimization problem for a single flight vehicle and the other is a differential game problem with a nonzero sum for two flight vehicles. In accordance with the approach proposed here, the Pontriagin maximum principle is used as the optimality principle. The numerical results obtained can be used in the development of navigation and maneuvering algorithms for on-board computers. V.L.

A93-18381
CALCULATION OF THE PARAMETERS OF A CRANE HELICOPTER WITH ONE DISABLED ENGINE [RASCHET PARAMETROV VERTOLETA-KRANA V SLUCHAE OTKAZA ODNOGO DVIGATELIA]
S. V. MAKLASHKIN *In* Problems in the aerodynamics and dynamics of flight vehicles in the light of K.E. Tsiolkovsky's ideas; Lectures Devoted to K.E. Tsiolkovsky's Ideas, 25th, Kaluga, Russia, Sept. 11-14, 1990, Transactions Moscow AN SSSR, Institut Istorii Estestvoznaniia i Tekhniki 1991 p. 26-33. In Russian. refs
Copyright
The objective of the study was to investigate the possibility of the safe landing of a crane helicopter with the load still attached in the case of the failure of one of the engines. During the maneuver, the helicopter must be controlled in such a way as to minimize the vertical velocity at the moment when the load touches the ground; after this, the helicopter may either hover or make a safe landing. In accordance with the approach proposed here, the control law is obtained in the form of a stepped function, which makes it possible to formulate the law by using a relatively small number of parameters. As an example, calculations are presented for the Mi-10 helicopter. V.L.

A93-18383
ESTIMATION OF THE EXTERNAL LOADING OF AIRSHIPS IN FLIGHT [OTSENKA VNESHNIKH VOZDEISTVII NA DIRIZHABL' V POLETE]
V. V. KOZLOV, M. P. NIKITIN, and S. I. POLIAKOV *In* Problems in the aerodynamics and dynamics of flight vehicles in the light of K.E. Tsiolkovsky's ideas; Lectures Devoted to K.E. Tsiolkovsky's Ideas, 25th, Kaluga, Russia, Sept. 11-14, 1990, Transactions Moscow AN SSSR, Institut Istorii Estestvoznaniia i Tekhniki 1991 p. 41-45. In Russian. refs
Copyright
The problem of estimating the external loads acting on airships in flight is investigated analytically by treating an airship as a system of two coupled rigid bodies. When deriving the equations of motion, the aerodynamic loads on the airship body are calculated by using a method which accounts for the effect of wind. The discrete gust parameters are determined by solving an optimization problem. As an example, calculations are carried out for two types of airships. V.L.

A93-18777
DEVELOPING CONTROL STRATEGIES FOR ASTOVL AIRCRAFT
R. W. PRATT (Loughborough Univ. of Technology, United Kingdom) *In* Flight simulation - European opportunities; Proceedings of the Conference, London, United Kingdom, May 1, 2, 1991 London Royal Aeronautical Society 1992 p. 18.1-18.7. refs
Copyright
The paper discusses the role of a conceptual model in the development of control strategies for an ASTOVL aircraft. The specification for such a model is described briefly in relation to current operations on the Harrier. The issues relating to the development of stylized tasks suitable for the assessment of handling qualities through piloted simulation are also addressed. It is argued that in any future research program it will be essential to balance the need for an FCS to stabilize the aircraft's open-loop dynamics and still offer the pilot a flexible system. In particular, the system must allow the able aviator to develop operating procedures beyond the range envisaged at the design stage. The key issue is not the number of inceptors, but who actually has control - pilot or computer. C.A.B.

A93-20132#
AN OVERVIEW OF THE SYSTEM IDENTIFICATION PROCEDURE WITH APPLICATIONS TO THE X-31 DROP MODEL
KEITH D. NODERER (Joint Inst. for Advancement of Flight Sciences, Hampton, VA) Jan. 1993 8 p. AIAA, Aerospace

Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0010) Copyright
An overview of the system identification process is presented with specific applications to the X-31 drop model. The specifications of the model and testing procedure are outlined and the method of gathering data is described. The process of conducting a data compatibility check is briefly explained. The use of modified stepwise regression (MSR) in determining the aerodynamic model structure and least square estimates of the corresponding parameters is presented with applications to both single maneuvers and partitioned data. The ability of MSR to choose significant terms, both linear and nonlinear, in the aerodynamic equations is discussed. As an example of the results obtained, the yawing-moment parameters for angles of attack from 25 to 45 degrees are presented and compared to the corresponding wind tunnel data. Author

A93-20138#
RUDDER AND ELEVATOR EFFECTS ON THE INCIPIENT SPIN CHARACTERISTICS OF A TYPICAL GENERAL AVIATION TRAINING AIRCRAFT
PATRICK R. VEILLETTE (Utah Univ., Salt Lake City) Jan. 1993 6 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0016) Copyright
Full scale flight tests were performed on a general aviation training aircraft to study the validity of the tail design criteria at incipient spin entry and recovery flight configurations. Pilot recognition of incipient spin and subsequent recovery maneuvers versus net altitude loss were also studied. It is concluded that future design criteria must account for the combined propwash/stall wake/wing downwash effect over the empennage. R.E.P.

A93-20169*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ACTIVE CONTROL OF WING ROCK OF A DELTA WING AT POST-STALL USING TANGENTIAL LEADING EDGE BLOWING
G. S. WONG, S. M. ROCK, N. J. WOOD, and L. ROBERTS (Stanford Univ., CA) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by USAF and NASA refs
(AIAA PAPER 93-0056) Copyright
Post-stall roll control utilizing tangential leading edge blowing is demonstrated in a wind tunnel on a delta wing model that exhibited wing rock. The dampening effect of symmetric blowing alone on wing rock is found to be effective up to a certain maximum amount of blowing. A moderate amount of symmetric blowing was shown to be effective in linearizing the asymmetric blowing static rolling moment responses. R.E.P.

A93-20812
A METHOD OF FINITE ELEMENT DYNAMIC MODEL OPTIMIZATION
MULAN CHEN (Research Inst. of Pilotless Aircraft, China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956) vol. 24, no. 5 Oct. 1992 p. 574-579. In Chinese. refs
A finite element dynamic model optimization is performed, taking the inherent frequency of an aircraft structure measured in vibration experiments as the target. A new iterative optimization method is applied, based on the dynamic equilibrium equations and orthogonality. The stiffness matrix elements are modified for optimization in order to calculate the inherent frequency in accordance with the measured frequencies. The method has been successfully applied to real models of the horizontal tail wing of a pilotless aircraft. B.J.

A93-20823
ANALYSIS OF APPROACH PATHS OF A SINGLE AIRCRAFT
KEI SUGIMOTO and KANICHIRO KATO Japan Society for Aeronautical and Space Sciences, Journal (ISSN 0021-4663) vol. 40, no. 467 1992 p. 674-681. In Japanese. refs
Approach paths of a single aircraft coming into a terminal area were solved numerically. The problem of calculating approach paths was formulated in terms of the optimal control problem. Inequality constraints of a state variable and control variables were taken into account so that numerical results might be consistent with approach paths of an actual aircraft. It was shown how the approach paths of a single aircraft depended upon functionals, initial conditions, and terminal conditions. Author

A93-21657
THRUST VECTORING - THEORY, LABORATORY, AND FLIGHT TESTS
BENJAMIN GAL-OR and VALERY SHERBAUM (Technion - Israel Inst. of Technology, Haifa) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 51-58. Research sponsored by USAF, General Dynamics Corp., General Electric Co., et al refs
Copyright
Novel thrust vectoring designs are presented which are optimized for poststall agility (PSA) maximization. These concepts are used as the bases for formulating a unified mathematical phenomenology for PSA-emphasizing fighter aircraft designs. The phenomenology is combined with an exotic methodology for testing agile, tailless thrust-vectoring fighter configuration alternatives, as well as for assessing the efficiency of thrust vectoring nozzle-retrofitted conventional fighters. Two control rules for PSA thrust vectoring are formulated. O.C.

A93-22285*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SUPERSONIC DYNAMIC STABILITY CHARACTERISTICS OF THE TEST TECHNIQUE DEMONSTRATOR NASP CONFIGURATION
DAVID A. DRESS, RICHMOND P. BOYDEN, and CHRISTOPHER I. CRUZ (NASA, Langley Research Center, Hampton, VA) Dec. 1992 16 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5009) Copyright
Wind tunnel tests of a National Aero-Space Plane (NASP) configuration were conducted in both test sections of the Langley Unitary Plan Wind Tunnel. The model used is a Langley designed blended body NASP configuration. Dynamic stability characteristics were measured on this configuration at Mach numbers of 2.0, 2.5, 3.5, and 4.5. In addition to tests of the baseline configuration, component buildup tests were conducted. The test results show that the baseline configuration generally has positive damping about all three axes with only isolated exceptions. In addition, there was generally good agreement between the in-pulse dynamic parameters and the corresponding static data which were measured during another series of tests in the Unitary Plan Wind Tunnel. Also included are comparisons of the experimental damping parameters with results from the engineering predictive code APAS (Aerodynamic Preliminary Analysis System). These comparisons show good agreement at low angles of attack; however, the comparisons are generally not as good at the higher angles of attack. Author

A93-22609#
WHAT MAKES THE COBRA MANEUVER POSSIBLE?
LARS E. ERICSSON (Lockheed Missiles & Space Co., Inc., Sunnyvale, CA) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0183) Copyright
The unsteady aerodynamics associated with a rapid pitch-up/pitch-down motion of an advanced aircraft, the so called 'Cobra' maneuver, have been analyzed. It is found that the maneuver could probably not be performed in laminar flow because of the expected nose-slice tendency based upon experimental results. The likely reason for the absence of nose-slice tendencies in full-scale flight is the existing coupling between boundary layer transition and vehicle motion. These results support the conclusion reached in earlier high-alpha analyses, i.e., dynamic simulation in subscale tests is only possible if the full-scale Reynolds number is simulated. Author

A93-22612*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

EXPERIMENTAL AND NUMERICAL ANALYSIS OF THE WING ROCK CHARACTERISTICS OF A 'WING-BODY-TAIL' CONFIGURATION

CARLOS J. SUAREZ, BROOKE C. SMITH, and GERALD N. MALCOLM (Eidetics International, Inc., Torrance, CA) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS2-12989)
(AIAA PAPER 93-0187) Copyright

Free-to-roll wind tunnel tests were conducted and a computer simulation exercise was performed in an effort to investigate in detail the mechanism of wing rock on a configuration that consisted of a highly-slender forebody and a 78 deg swept delta wing. In the wind tunnel test, the roll angle and wing surface pressures were measured during the wing rock motion. A limit cycle oscillation was observed for angles of attack between 22 deg and 30 deg. In general, the wind tunnel test confirmed that the main flow phenomena responsible for the wing-body-tail wing rock are the interactions between the forebody and the wing vortices. The variation of roll acceleration (determined from the second derivative of the roll angle time history) with roll angle clearly showed the energy balance necessary to sustain the limit cycle oscillation. Pressure measurements on the wing revealed the hysteresis of the wing rock process. First, second and nth order models for the aerodynamic damping were developed and examined with a one degree of freedom computer simulation. Very good agreement with the observed behavior from the wind tunnel was obtained.
Author

A93-22865

APPLICATION OF STRUCTURED SINGULAR VALUE SYNTHESIS TO A FIGHTER AIRCRAFT

ANDREW SPARKS and SIVA BANDA (USAF, Wright Lab., Wright-Patterson AFB, OH) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1301-1305. refs
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The results of a design study to examine the control of a fighter aircraft at high angles of attack are presented. The flight condition considered represents an extreme point along a demanding large angle maneuver. Control laws are developed for a linear model of the aircraft using structured singular value synthesis to take the parameter uncertainty structure into account. The control objective is to attain acceptable flying qualities despite variations and uncertainty in the aircraft's aerodynamic coefficients. Desired flying qualities are embedded in ideal models of the angle of attack, sideslip angle, and stability axis roll rate responses to pilot inputs. The control objective is met by minimizing the weighted error between the ideal model outputs and the plant outputs while including structured parameter uncertainty in the design model.
I.E.

A93-22868

NONLINEAR AIRCRAFT FLIGHT CONTROL USING DYNAMIC INVERSION

KEVIN A. WISE (McDonnell Douglas Missile Systems Co., Saint Louis, MO) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1322-1326. refs
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Post-stall maneuvers in air-to-air combat extend the aircraft's operating regime into an unstable, nonlinear, high angle-of-attack (alpha) aerodynamic environment. The research in flight control addresses this important and difficult problem. The author summarizes results that pertain to a nonlinear design created using dynamic inversion. The goal is to improve upon the sideslip and lateral acceleration responses during high alpha roll maneuvers. Linear and nonlinear autopilot design are considered. Digital implementation is discussed. The nonlinear flight control system design presented performed very well during simulation tests.
I.E.

A93-22869

DEVELOPMENT AND APPLICATION OF A NONLINEAR FIN MIXER

RICHARD D. JONES and JOSEPH A. BOSSI (Boeing Defense and Space Group, Seattle, WA) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1327-1331. refs
Copyright

The authors describe the development and application of a nonlinear fin mixer to control aerodynamic vehicles during demanding flight maneuvers. Maneuvers that may be experienced by a bank-to-turn homing missile utilizing a proportional navigation guidance scheme often drive fin actuators into acceleration, rate and/or position limitations. For vehicles where each fin is used to control multiple degrees-of-freedom, these saturations can lead to vehicle instability. These regions of instability are explored and a nonlinear fin mixer is developed which utilizes information on the actuator limitations to eliminate the instabilities in an optimal manner. It is shown that such a nonlinear mixer can be implemented with an artificial neural network. These improvements are demonstrated, using realistic six degree-of-freedom time simulation.
I.E.

A93-22882

REFINED H-INFINITY CONTROLLER DESIGN FOR ROTORCRAFT FLIGHT CONTROL

JIEH-SHIAN YOUNG and CHIN E. LIN (National Cheng Kung Univ., Tainan, Taiwan) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1523-1528. refs
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The authors present an approach to refine the H-infinity-optimal controller for the four-block H-infinity control problem. The diagonalizing matrix pair which connects the successive layers is constructed. The synthesis of the sublayers that refines the optimal solution of the major layer is considered. The second singular value of the compensated system can be analyzed and synthesized with a free parameter by the proposed approach, which is implementable in terms of computation with appropriate selection of the diagonalizing matrix pair. The H-infinity-norm of the sublayers can, therefore, be improved. An engineering application related to rotor-craft flight control is provided. The simulation results showed that the performance was improved in the frequency domain.
I.E.

A93-22883

A NEW FLIGHT CONTROL DESIGN SCHEME USING OPTIMAL DYNAMIC OUTPUT FEEDBACK

CHIU-PIN CHENG (National Cheng Kung Univ., Tainan, Taiwan), TZUU-HSENG S. LI, and CHING-FANG LIN (American GNC Corp. Chatsworth, CA) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1529-1533. refs
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The authors apply a newly developed optimal dynamic output feedback control method to control the angle of attack alpha and pitch angle phi, and the angle of sideslip beta and roll angle theta, so that the pilot can maneuver and control the aircraft to the desired flight attitude precisely. The control design model is based on the linearized aircraft model. The unmodeled high frequency dynamics are ignored in this model. A singular perturbation method is used to analyze the effects of the unmodeled high frequency dynamics of the proposed controller. It is shown that the unmodeled dynamics affect the poles of the closed-loop system on the order of O(epsilon) only. The computer simulations verify the desired performance of the proposed scheme.
I.E.

A93-22884

VERTICAL GUIDANCE FOR A LOCKHEED L1011-100 USING OPTIMAL DYNAMIC INTERPOLATION

CHARLES R. TOLLE and ARMANDO A. RODRIGUEZ (Arizona State Univ., Tempe) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1534-1538. Research supported by Arizona State Industrial Fellows Program, Honeywell, Inc., and Arizona State Univ refs

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Dynamic interpolation is applied to an L1011-100 vertical guidance problem. A flight management system's (FMS's) optimized vertical flight plan is used to obtain way points which serve as inputs to the dynamic interpolation algorithm. The algorithm produces reference commands which are issued to a FAA certified six degree of freedom L1011-100 model, valid up to 20,000 feet, and a L1011 simulated autopilot. The resulting dynamic behavior is compared to the results obtained from reference commands produced by an L1011-like commercial aircraft FMS. Quadratic and cubic spline solutions to the dynamic interpolation problem are presented. Performance degradation with respect to weight uncertainty is examined for both the FMS and the dynamic interpolation commands. I.E.

A93-22885

USING SYSTEM IDENTIFICATION TO IMPROVE THE PERFORMANCE OF A LOW-COST FLIGHT SIMULATOR

KUO-CHI LIN (Central Florida Univ., Orlando, FL) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1539-1543. Research supported by DARPA refs

(Contract N61339-89-C-0045)

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The Avionics Situational Awareness Trainer (ASAT) flight simulator is limited by its hardware and cannot provide good flight dynamic models. The author proposes a possible solution using the concept of system identification. The measured data were taken from the flight tests of a high-fidelity flight simulator. The flight dynamic model of the ASAT is used as the candidate model. The adjustable parameters in the candidate model are estimated by matching time-domain data. A comparison of the results between the ASAT and the high-fidelity simulator is given. The new flight dynamics model improved the ASAT roll performance. I.E.

A93-22886

TURBULENCE/GUST ALLEVIATION USING SPOILER CONTROL

X. D. SUN and J. C. ALLWRIGHT (Imperial College of Science, Technology, and Medicine, London, United Kingdom) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1544, 1545. refs

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The authors present recent work on applications of spoiler control to aircraft maneuvering enhancement and gust alleviation. The nonlinear inverse dynamics control technique is applied to the synthesis of a decoupled model-following flight control system for an aircraft with spoilers. Various control modes and objectives, based on selected command variables and control inputs, were studied and evaluated by simulations. In particular, some specified in-turbulence flight simulations were made to show the effectiveness of spoiler control on turbulence/gust alleviation. I.E.

A93-22887

DYNAMICAL VARIABLE STRUCTURE CONTROL OF A HELICOPTER IN VERTICAL FLIGHT

HEBERTT SIRA-RAMIREZ (Los Andes Univ., Merida, Venezuela), MOHAMED ZRIBI, and SHAHEEN AHMAD (Purdue Univ., West Lafayette, IN) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1546-1550. Research supported by Universidad de Los Andes and Shin Meiwa Industries, Ltd refs

Copyright

A dynamical multivariable discontinuous feedback control strategy of the sliding mode type is proposed for the altitude stabilization of a nonlinear helicopter model in vertical flight. The authors present the nonlinear model and the corresponding dynamical sliding mode controller design for altitude and the rotor pitch angle regulation. Computer-generated simulation results are presented and discussed. While retaining the basic robustness features associated to sliding mode control policies, the proposed approach also results in smoothed out, i.e., nonchattering, input trajectories and controlled state variable responses. I.E.

A93-22905

CONTROL OF A HIGH PERFORMANCE AIRCRAFT WITH UNACCEPTABLE ZERODYNAMICS

SWAMINATHAN GOPALSWAMY and J. K. HEDRICK (California Univ., Berkeley) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 3 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1834-1838. refs

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Computer simulations of the pitch axis dynamics of an AFTI-F16 during a 6-g pull-up maneuver were performed. As expected, the zero dynamics associated with the output are unacceptable, and therefore direct application of standard nonlinear techniques such as the input-output linearization technique fails. An output redefinition technique is used to systematically overcome the zero-dynamics problem, resulting in precise, local tracking. I.E.

A93-22937

NEW RESULTS IN OPTIMAL MISSILE AVOIDANCE ANALYSIS

J. SHINAR and R. TABAK (Technion - Israel Inst. of Technology, Haifa) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 3 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 2375-2379. refs

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Optimal missile avoidance of a constant-speed aircraft from a coasting missile of first-order dynamics, guided by proportional navigation, is analyzed in the plane. This model allows the investigation of the missile outrunning and end game evasion maneuvers in the same engagement. Three regions of different optimal avoidance strategies are identified. All strategies are compromises in satisfying different optimal evasion principles: bleeding energy from the missile and minimizing of the closing velocity (principles of missile outrunning), and a final maneuver of a critical duration, perpendicular to the line of sight (principles of optimal end game evasion). Due to the missile's aerodynamic drag the aircraft is able to reduce missile maneuverability by an outrunning maneuver so that in the end-game a larger miss distance can be generated. I.E.

A93-22980

APPLICATION OF THE RECEDING HORIZON STRATEGY TO SINGULARLY PERTURBED PURSUIT-EVASION PROBLEMS

J. SHINAR and V. Y. GLIZER (Technion - Israel Inst. of Technology, Haifa) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 4 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 3247, 3248. refs

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Time-optimal interception of an arbitrarily maneuvering opponent is investigated. A novel guidance algorithm based on a 'receding horizon' strategy is shown to be efficient and an attractive candidate for real-time application. The receding horizon guidance algorithm is an efficient compromise for the interception of an arbitrarily maneuvering evader. In most situations the potential performance loss, with respect to the true optimal solution, is negligible. In any case, the performance loss of the receding horizon control is always less than that of a pursuer strategy optimized against the

'wrong' evader. The receding horizon algorithm is easy to implement and robust, with respect to the classical (optimal control and differential game) alternatives. I.E.

A93-23073*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

ICING EFFECTS ON AIRCRAFT STABILITY AND CONTROL DETERMINED FROM FLIGHT DATA - PRELIMINARY RESULTS

T. P. RATVASKY and R. J. RANAUDO (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 27 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-14831 refs
(AIAA PAPER 93-0398) Copyright

The effects of airframe icing on the stability and control characteristics of the NASA DH-6 Twin Otter icing research aircraft were investigated by flight test. The flight program was developed to obtain stability and control parameters of the DH-6 in a baseline ('uniced') configuration and an 'artificially iced' configuration for specified thrust conditions. Stability and control parameter identification maneuvers were performed over a wide range of angles of attack for wing flaps retraced (0 deg) and wing flaps partially deflected (10 deg). Engine power was adjusted to hold thrust constant at one of three thrust coefficients (C(sub T) = 0.14, C(sub T) = 0.07, C(sub T) = 0.00). This paper presents only the pitching- and yawing-moment results from the flight test program. Stability and control parameters were estimated for the uniced and artificially iced configurations using a modified stepwise regression algorithm. Comparisons of the uniced and iced stability and control parameters are presented for the majority of the flight envelope. The artificial ice reduced the elevator and rudder control effectiveness by 12 percent and 8 percent respectively for the 0 deg flap setting. The longitudinal static stability was also decreased substantially (approximately 10 percent) because of the tail ice. Further discussion is provided to explain some of the effects of ice on the stability and control parameters. Author

A93-23255*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

STABILITY AND CONTROL OF HYPERSONIC WAVERIDERS

CHRISTOPHER TARPLEY and MARK J. LEWIS (Maryland Univ., College Park) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NCA2-611)
(AIAA PAPER 93-0508) Copyright

The longitudinal and lateral stability derivatives of caret-wing waveriders flying on-design are calculated using linear piston theory. The experimental work of Kipke is used to validate the lift and pitch stiffness coefficients. Comparison is also made to the analytical work done by Hui. The calculations are extended to off-design conditions with an attached shock wave using tangent wedge theory. The stability derivatives of a Mach 6 waverider are computed and conclusions about its stability are drawn. Author

A93-23509

DESIGN OF FLIGHT CONTROL SYSTEMS TO MEET ROTORCRAFT HANDLING QUALITIES SPECIFICATIONS

EICHER LOW and WILLIAM L. GARRARD (Minnesota Univ., Minneapolis) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 1 Jan.-Feb. 1993 p. 69-78. Previously cited in issue 20, p. 3154, Accession no. A90-45140 refs
(Contract DAAL03-86-K-0056)
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A93-23511

THREE-DIMENSIONAL MODELING AND CONTROL OF A TWIN-LIFT HELICOPTER SYSTEM

MANOJ MITTAL and J. V. R. PRASAD (Georgia Inst. of Technology, Atlanta) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 1 Jan.-Feb. 1993 p. 86-95. Previously cited in issue 21, p. 3600, Accession no. A91-49711 refs
Copyright

A93-23514

APPLICATION OF FEEDBACK LINEARIZATION METHOD IN A DIGITAL RESTRUCTURABLE FLIGHT CONTROL SYSTEM

YOSHIMASA OCHI (National Defense Academy, Yokosuka, Japan) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 1 Jan.-Feb. 1993 p. 111-117. refs
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The proposed control system is applied to aircraft failures occurring with the control effectors or airframe. The failures are identified as parameter changes in the six-degree-of-freedom nonlinear equations of motion by the recursive least-squares algorithm. The control parameters are updated using the latest estimated system parameters. In order to allow one to use a digital computer in implementations, a discrete-time servo controller is designed for the actuators of the control surfaces and engine. The reference inputs are given by the continuous-time control law that is derived without considering actuator or engine dynamics. The frequency-dependent optimal regulator is employed in the design of the servo controller to eliminate input fluctuation. Performance of the control system is demonstrated through computer simulation using the nonlinear model of an aircraft that has half its right wing broken off. Author

A93-23515

DESIGN OF INSENSITIVE MULTIRATE AIRCRAFT CONTROL USING OPTIMIZED EIGENSTRUCTURE ASSIGNMENT

Y. PATEL, R. J. PATTON, and S. P. BURROWS (York Univ., United Kingdom) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 1 Jan.-Feb. 1993 p. 118-123. Research supported by British Aerospace, SERC, and Ministry of Defence of United Kingdom refs
Copyright

A new method is proposed for the design of constant-gain controllers for digital aircraft systems monitored and updated at multiple frequencies. The design approach provides an optimized solution to the eigenstructure-assignment problem for multirate structures with multiple-input/fixed-output sample rates. The optimization task is to minimize a scalar cost function that measures both the demanded control effort and the modal interactions of the closed-loop system. The application of the method is demonstrated by considering the design of two multivariate state feedback control laws for the lateral subsystem of an aircraft. V.L.

A93-23516

OPTIMAL CONTROL LAW SYNTHESIS FOR FLUTTER SUPPRESSION USING ACTIVE ACOUSTIC EXCITATIONS

PONG-JEU LU and LI-JENG HUANG (National Cheng Kung Univ., Tainan, Taiwan) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 1 Jan.-Feb. 1993 p. 124-131. refs
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This paper describes a development of the optimal control law design procedure for the flutter suppression of airfoils using active acoustic excitations. A bending-torsion typical section and a two-dimensional incompressible aerodynamic model are adopted for the present analysis. An irreducible state-space description of the aeroservoelastic system is constructed via the use of Hankel matrices and the singular value decomposition method. The evaluation of the degree of controllability/observability and the synthesis of the optimal control law using steady-state linear quadratic regulator theory accompanied by an asymptotic state observer are performed. This optimal control law design enables the search of the most effective position to locate the sound wave generator. The trailing edge is shown to be the best region for installing the sound wave generator, where the highest degree of controllability and the minimal control effort are attained. A case study shows that approximately 20 dB reduction in sound pressure level can be achieved using this optimal control law design. Author

N93-16165# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
MULTIPLE MODEL ADAPTIVE ESTIMATION APPLIED TO THE VISTA F-16 WITH ACTUATOR AND SENSOR FAILURES, VOLUME 2 Final Report
TIMOTHY E. MENKE 1 Jun. 1992 244 p
(AD-A256569; AFIT/GA/ENG/92J-01-VOL-2) Avail: CASI HC A11/MF A03

A Multiple Model Adaptive Estimation (MMAE) algorithm is applied to the Variable Stability In-flight Simulator Test Aircraft (VISTA) F-16 at a low dynamic pressure flight condition (0.4 Mach at 20000 ft). A complete F-16 flight control system is modeled containing the longitudinal and lateral-directional axes. Single and dual actuator and sensor failures are simulated including: complete actuator failures, partial actuator failures, complete sensor failures, increased sensor noise, sensor biases, dual complete actuator failures, dual complete sensor failures, and combinations of actuator and sensor failures. Failure scenarios are examined in both maneuvering and straight and level flight conditions. The system performance is characterized when excited by purposeful commands and dither signals. Single scalar residual monitoring techniques are evaluated with suggestions for improved performance. A Kahnan filter is designed for each hypothesized failure condition. In this thesis, thirteen elemental Kalman filters are designed encompassing: a no failure filter, left stabilator failure filter, a right stabilator failure filter, a left flaperon failure filter, a right flaperon failure filter, a rudder failure filter, a velocity sensor failure filter, an angle of attack sensor failure filter, a pitch rate sensor failure filter, a normal acceleration sensor failure filter, a roll rate sensor failure filter, a yaw rate sensor failure filter, and a lateral acceleration sensor failure filter. GRA

N93-16463 Department of the Navy, Washington, DC.
ARTICULATED CONTROL SURFACE Patent
MANUEL CINCOTTA, inventor (to Navy) and RICHARD H. NADOLINK, inventor (to Navy) 19 May 1992 6 p Filed 1 Oct. 1990
(AD-D015464; US-PATENT-5,114,104; US-PATENT-APPL-SN-591532; US-PATENT-CLASS-244-219)
Avail: US Patent and Trademark Office

An articulated control surface for flight control utilizes a moldable control surface that is shaped by contracting and elongating shape memory alloys embedded within the control surface. The shape memory alloys contract when heated via an applied electric current and elongate when cooled, i.e., the electric current is removed. The resulting control surface is capable of generating a curved control surface without any electro/mechanical or hydraulic control systems. GRA

N93-16560*# Toledo Univ., OH. Dept. of Mechanical Engineering.
AEROELASTIC STABILITY AND RESPONSE OF ROTATING STRUCTURES Final Technical Report
THEO G. KEITH, JR. Jan. 1993 7 p
(Contract NSG-3139)
(NASA-CR-191803; NAS 1.26:191803) Avail: CASI HC A02/MF A01

A summary of the work performed during the progress period is presented. Analysis methods for predicting loads and instabilities of wind turbines were developed. Three new areas of research to aid the Advanced Turboprop Project (ATP) were initiated and developed. These three areas of research are aeroelastic analysis methods for cascades including blade and disk flexibility; stall flutter analysis; and computational aeroelasticity. L.R.R.

N93-16618# Technische Univ., Munich (Germany). Dept. of Mathematics.
COMBINING DIRECT AND INDIRECT METHODS IN OPTIMAL CONTROL: RANGE MAXIMIZATION OF A HANG GLIDER
R. BULIRSCH, E. NERZ, H. J. PESCH, and O. VONSTRYK 1991 25 p
(REPT-313) Avail: CASI HC A03/MF A01

When solving optimal control problems, indirect methods such as multiple shooting suffer from difficulties in finding an appropriate initial guess for the adjoint variables. This initial estimate must be provided for the iterative solution of the multipoint boundary-value problems arising from the necessary conditions of optimal control theory. Direct methods such as direct collocation do not suffer from this problem, but they generally yield results of lower accuracy, and, what may be disasterous, their iteration may even terminate with a non-optimal solution. Therefore, both methods are combined in such a way that the direct collocation method is at first applied to a simplified optimal control problem where all inequality constraints are neglected as long as the resulting problem is still well-defined. Because of the larger domain of convergence of the direct method, an approximation of the optimal solution of this problem can be obtained more easily. The fusion between direct and indirect methods is then based on a relationship between the Lagrange multipliers of the underlying nonlinear programming problem to be solved by the direct method and the adjoint variables appearing in the necessary conditions which form the boundary-value problem to be solved by the indirect method. Hence, the adjoint variables, too, can be estimated from the approximation obtained by the direct method. This first step then facilitates the subsequent extension and completion of the model by homotopy techniques and the solution of the arising boundary-value problems by the indirect multiple shooting method. The high accuracy and reliability of the multiple shooting method, especially the precise computation of the switching structure and the possibility to verify many necessary conditions, is preserved while disadvantages caused by the sensitive dependence on an appropriate estimate of the solution are considerably cut down. This procedure is described in detail for the numerical solution of the maximum-range trajectory optimization problem of a hang glider in an upwind which provides an example for a control problem where appropriate initial estimates for the adjoint variables are hard to find. Author

N93-16769*# Michigan State Univ., East Lansing. Dept. of Mechanical Engineering.
DEVELOPING A CONTROL SYSTEM FOR ARES 2
PHILIP M. FITZSIMONS *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 106-109 Sep. 1992
Avail: CASI HC A01/MF A03

A great deal of analysis and testing is conducted at the NASA Langley Research Center to support the development of safe and reliable helicopter rotor systems. This work is performed by the Rotorcraft Aeroelasticity Group located in the Transonic Dynamics Tunnel (TDT) facility. Over the past two decades a wide variety of tests have been successfully conducted in the TDT and their results have contributed significantly to the understanding of aeromechanical phenomena in rotor systems. This has led to improved tools for analysis and design, and ultimately to the development, of improved rotor systems. The TDT facility is ideally suited for these tests due to its unique ability to use a heavy gas as a working medium. This allows the model to be scaled such that the results obtained may be readily extrapolated to full scale. Until recently, the rotor system to be tested has been mounted on a fixed balance which is attached to the longeron which is attached to the stand through a single pitching degree of freedom. The testbed used is known as the Aeroelastic Rotor Experimental System (ARES 1). In order to extend the experimental capabilities to investigate the full rotor/body dynamic coupling present in a rotorcraft, a very ambitious project has been undertaken to design and construct a six degree of freedom system that can be controlled so as to emulate the inertial characteristics of a prescribed model fuselage. The electronic and mechanical hardware for this system has already been designed and constructed. This system is known ar ARES II. The rotor and its drive system are mounted on the balance which is attached to the longeron via six hydraulic actuators. This six degree of freedom parallel linkage is referred to in the literature as a Stuart Platform. By properly adjusting the length of the hydraulic actuators it is possible to position and orient the balance relative to the longeron. The longeron is attached to the stand via a pitch degree of freedom to allow testing over

various forward flight regimes. One major task remaining to complete this testbed is the design and synthesis of a control system. To do this properly requires an understanding of the kinematics and dynamics of the system and robust control design. A brief description of the development of a control design is given. Author

N93-17670# Naval Postgraduate School, Monterey, CA.
DESIGN OF ROBUST SUBOPTIMAL CONTROLLERS FOR A GENERALIZED QUADRATIC CRITERION M.S. Thesis
KURTIS B. MILLER Jun. 1992 66 p
(AD-A257746) Avail: CASI HC A04/MF A01

Standard linear quadratic regulator (LQR) designs guarantee a certain level of robustness. However, optimizing a generalized quadratic criterion produces coupled state and input terms and there are no longer any guarantees of good robustness properties. This thesis identifies how this problem arises and then presents several suboptimal, but robust controller design options which provide the control systems engineer with the ability to perform a trade-off between performance and robustness. The effectiveness of these methods is investigated and the trade-offs between performance and robustness are evaluated using computer simulation of a statically unstable fighter aircraft. GRA

N93-17800*# California Polytechnic State Univ., San Luis Obispo. Dept. of Aeronautical Engineering.
LOW BANDWIDTH ROBUST CONTROLLERS FOR FLIGHT Final Report, Jun. 1991 - Dec. 1992
DANIEL J. BIEZAD and HWEI-LAN CHOU 1992 50 p
(Contract NCC2-711)
(NASA-CR-191774; NAS 1.26:191774) Avail: CASI HC A03/MF A01

During the final reporting period (Jun. - Dec. 1992), analyses of the longitudinal and lateral flying qualities were made for propulsive-only flight control (POFC) of a Boeing 720 aircraft model. Performance resulting from compensators developed using Quantitative Feedback Theory (QFT) is documented and analyzed. This report is a first draft of a thesis to be presented by graduate student Hwei-Lan Chou. The final thesis will be presented to NASA when it is completed later this year. The latest landing metrics related to bandwidth criteria and based on the Neal-Smith approach to flying qualities prediction were used in developing performance criteria for the controllers. The compensator designs were tested on the NASA simulator and exhibited adequate performance for piloted flight. There was no significant impact of QFT on performance of the propulsive-only flight controllers in either the longitudinal or lateral modes of flight. This was attributed to the physical limits of thrust available and the engine rate of response, both of whiih severely limited the available bandwidth of the closed-loop system. Author

N93-18142# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
INTRODUCTION TO FLUTTER OF WINGED AIRCRAFT, VOLUME 1
1992 356 p Lecture series held in Rhode-Saint-Genese, Belgium, 9-13 Dec. 1991
(ISSN 0377-8312)
(VKI-LS-1992-01; ETN-93-92618) Avail: CASI HC A16/MF A03

This volume is part of a lecture series in which a number of basic and new ideas on wing flutter are presented to both the uninitiated and experienced engineer. The lectures were designed to present the physical phenomenon, the mathematical modeling of the physics (covering the interaction among the inertial and elastic energies of the wing with the energies associated with the airstream), and the instability of the wing that might arise. In this volume a single paper concerning the unified method of elasticity is presented. The basic concepts of the unified method needed by engineers in understanding the techniques for incorporating aeroelastic effects in stability analyses of winged aircraft are presented, and practical procedures for performing such analyses are given. ESA

N93-18143# Naval Academy, Annapolis, MD. Dept. of Mechanical Engineering.
THE UNIFIED METHOD OF AEROELASTICITY
ROBERT A. GRANGER *In* VKI, Introduction to Flutter of Winged Aircraft, Volume 1 347 p 1992
Avail: CASI HC A15/MF A03

The basic concepts of the unified method needed by engineers in understanding the techniques for incorporating aeroelastic effects in stability analyses of winged aircraft are presented, and practical procedures for performing such analyses are given. Kernel functions and operators are discussed. Within the framework of structural analyses, the conduction of vibration and static deflection analyses are considered. That aspect of Lagrange's equations of motion involving the external part of the system, the aerodynamics of the generalized forces and moments, are considered. The problem of determining the nature of the aerodynamic forces is discussed. These forces are independent of the static forces which are essential to keep the system in dynamic equilibrium. The forces considered maintain oscillations about this dynamic equilibrium state. The unified method is compared with the piston theory and it is found that the former is more accurate at low Mach numbers but is more restrictive with regards to the frequency. ESA

N93-18193# Naval Postgraduate School, Monterey, CA.
IDENTIFICATION AND CONTROL OF NON-LINEAR TIME-VARYING DYNAMICAL SYSTEMS USING ARTIFICIAL NEURAL NETWORKS Ph.D. Thesis
SHAHAR DROR Sep. 1992 285 p
(AD-A257595) Avail: CASI HC A13/MF A03

Identification and control of non-linear dynamical systems is a very complex task which requires new methods. This research addresses the problem of emulation and control via the use of distributed parallel processing, namely artificial neural networks. Four models for describing non-linear MIMO dynamical systems are presented. Based on these models, combined feedforward and recurrent neural networks are structured to emulate the dynamical system. Further, a procedure to emulate multiple systems in a single network is suggested. A method for finding a minimal realization of a network is introduced. The minimization greatly reduces the complexity of the network without degrading the operating performance of the network. This work also examines the application of artificial neural networks for adaptive control. The multiple-system approach is used to find an adaptive neural network controller for non-linear MIMO time-varying system in a direct model reference control scheme. The controller network is trained using a procedure called back-propagation through the plant, which was extended in this work. The application of neural networks is demonstrated on a longitudinal model of the F/A-18A fighter aircraft, both with the undamaged aircraft and with the mechanism as a time-varying MIMO dynamical system. GRA

N93-19019 Virginia Polytechnic Inst. and State Univ., Blacksburg.
FORMULATION OF A STRUCTURAL MODEL FOR FLUTTER ANALYSIS OF LOW ASPECT RATIO COMPOSITE AIRCRAFT WINGS Ph.D. Thesis
TIMOTHY J. SEITZ 1992 92 p
Avail: Univ. Microfilms Order No. DA9301017

The research contributes toward a fully integrated multidisciplinary wing design synthesis by development of an appropriate structural model. The goal is to bridge the gap between highly idealized structural beam/aerodynamic strip models and the very detailed finite element and computational fluid dynamics, FEM/CFD, techniques. The former provides insufficient accuracy for flutter analysis of modern low aspect ratio composite wings. The latter is too computationally intensive for use in the inner loop of a simultaneous multidisciplinary optimization problem. The derived model provides a useful preliminary design tool as well. Dissert. Abstr.

N93-19095# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
STRATEGIES FOR OPTIMAL CONTROL DESIGN OF NORMAL ACCELERATION COMMAND FOLLOWING ON THE F-16 M.S. Thesis
JAMES C. BAIRD Dec. 1992 197 p
(AD-A258975; AFIT/GAE/ENY/92D-08) Avail: CASI HC A09/MF A03

Weight shapes and locations are investigated for H2, H-infinity, and the general mixed H2/H-infinity optimization methodologies. The design model is normal acceleration command following for the F-16 (SISO) at Mach 0.6 and Sea Level, which yields a nonminimum phase and unstable plant. H2 design types include LQG, LQG/Sensitivity, and LQG/Tracking. Robustness and tracking are the objectives of the central H-infinity process. Both H-infinity optimal and suboptimal controllers are examined, with the suboptimal controller shown as the practical choice for this plant. The mixed H2/H-infinity setup allows the tradeoff between H2 tracking and noise rejection, and H-infinity robustness. Results of weight choices on all designs are discussed, with the mixed H2/H-infinity design being favored. GRA

N93-19108*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
LONGITUDINAL-CONTROL DESIGN APPROACH FOR HIGH-ANGLE-OF-ATTACK AIRCRAFT
AARON J. OSTROFF and MELISSA S. PROFFITT (Lockheed Engineering and Sciences Co., Hampton, VA.) Washington Feb. 1993 29 p
(Contract RTOP 505-64-30-01)
(NASA-TP-3302; L-17123; NAS 1.60:3302) Avail: CASI HC A03/MF A01

This paper describes a control synthesis methodology that emphasizes a variable-gain output feedback technique that is applied to the longitudinal channel of a high-angle-of-attack aircraft. The aircraft is a modified F/A-18 aircraft with thrust-vectored controls. The flight regime covers a range up to a Mach number of 0.7; an altitude range from 15,000 to 35,000 ft; and an angle-of-attack (alpha) range up to 70 deg, which is deep into the poststall region. A brief overview is given of the variable-gain mathematical formulation as well as a description of the discrete control structure used for the feedback controller. This paper also presents an approximate design procedure with relationships for the optimal weights for the selected feedback control structure. These weights are selected to meet control design guidelines for high-alpha flight controls. Those guidelines that apply to the longitudinal-control design are also summarized. A unique approach is presented for the feed-forward command generator to obtain smooth transitions between load factor and alpha commands. Finally, representative linear analysis results and nonlinear batch simulation results are provided. Author

N93-19351# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
HELICOPTER FLIGHT CONTROL SYSTEM DESIGN USING THE LINEAR QUADRATIC REGULATOR FOR ROBUST EIGENSTRUCTURE ASSIGNMENT M.S. Thesis
DEMPSEY D. SOLOMON Dec. 1992 98 p
(AD-A258904; AFIT/GAE/ENY/92D-17) Avail: CASI HC A05/MF A02

This thesis applied modern, multi-variable control design techniques, via a FORTRAN computer algorithm, to U.S. Army helicopter models in hovering flight conditions. Eigenstructure assignment and Linear Quadratic Regulator (LQR) theory are used to achieve enhanced closed loop performance and stability characteristics with full state feedback. The addition of cross coupling weights to the standard LQR performance index is specifically addressed. A desired eigenstructure is chosen with a goal of reduced pilot workload via performance qualities requirements. Cross coupling weighting is shown to provide greater flexibility in achieving a desired closed loop eigenstructure. While the addition of cross coupling weighting is shown to eliminate stability margin guarantees associated with LQR methods, the modified algorithm can achieve a closer match to a desired eigenstructure than previous versions of the program while maintaining acceptable stability characteristics. GRA

N93-19380*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AN EXPLORATORY INVESTIGATION OF THE FLIGHT DYNAMICS EFFECTS OF ROTOR RPM VARIATIONS AND ROTOR STATE FEEDBACK IN HOVER
ROBERT T. N. CHEN Sep. 1992 43 p Presented at the 18th European Rotorcraft Forum, Avignon, France, 15-18 Sep. 1992
(Contract RTOP 505-59-36)
(NASA-TM-103968; A-92173; NAS 1.15:103968) Avail: CASI HC A03/MF A01

This paper presents the results of an analytical study conducted to investigate airframe/engine interface dynamics, and the influence of rotor speed variations on the flight dynamics of the helicopter in hover, and to explore the potential benefits of using rotor states as additional feedback signals in the flight control system. The analytical investigation required the development of a parametric high-order helicopter hover model, which included heave/yaw body motion, the rotor speed degree of freedom, rotor blade motion in flapping and lead-lag, inflow dynamics, a drive train model with a flexible rotor shaft, and an engine/rpm governor. First, the model was used to gain insight into the engine/drive train/rotor system dynamics and to obtain an improved simple formula for easy estimation of the dominant first torsional mode, which is important in the dynamic integration of the engine and airframe system. Then, a linearized version of the model was used to investigate the effects of rotor speed variations and rotor state feedback on helicopter flight dynamics. Results show that, by including rotor speed variations, the effective vertical damping decreases significantly from that calculated with a constant speed assumption, thereby providing a better correlation with flight test data. Higher closed-loop bandwidths appear to be more readily achievable with rotor state feedback. The results also indicate that both aircraft and rotor flapping responses to gust disturbance are significantly attenuated when rotor state feedback is used. Author

09

RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

A93-18357
A SYSTEM FOR WASHING THE COMBUSTION CHAMBER NOZZLES AND FLOW PATH COMPONENTS OF THE NK-8-2U ENGINE DURING SERVICE [USTANOVKA DLIA PROMYVKI FORSUNOK KAMERY SGORANIIA I PROTOCHNOI CHASTI DVIGATELIA NK-8-2U V EKSPLUATATSII]
B. F. BANBAN *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 26-28. In Russian. refs
Copyright

The hydraulic scheme and operation of a standard system for washing the fuel collectors and nozzles of the NK-8-2U engine are briefly described. The system has been upgraded to add the capability of simultaneously cleaning the flow path components of the gas turbine engine. The improved system has made it possible to decrease the total labor requirements for the simultaneous nozzle and flow path wash by a factor of 4. V.L.

A93-18362
VIBRATIONAL MONITORING AND DIAGNOSTICS OF THE TECHNICAL CONDITION OF GAS TURBINE ENGINES AT CIVIL AVIATION REPAIR FACILITIES [VIBRATSIONNYI KONTROL' I DIAGNOSTIROVANIE TEKHNICHESKOGO SOSTOIANIIA GTD NA AVIAREMONTNYKH PREDPRIIATIIAKH GRAZHDANSKOI AVIATSII]
V. IU. KOLOBANOV, IU. I. MANUKHOV, A. V. SINENKO, and V. A. FEDOT'EV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 47-50. In Russian.
Copyright
The existing and promising new methods and equipment for the vibrational diagnostics of gas turbine engines during bench testing at aircraft repair facilities are analyzed. A unified general-purpose vibrational control and diagnostic system for aircraft gas turbine engines is proposed. A block diagram of the proposed system is included. V.L.

A93-18529
LABORATORY FOR MODELLING OF PROSPECTIVE BOARD EQUIPMENT SYSTEMS FOR AIRCRAFT [LABORATORIUM DO MODELOWANIA PERSPEKTYWICZNYCH SYSTEMOW WYPOSAZENIA POKLADOWEGO SAMOLOTU]
STEFAN BRAMSKI (Inst. Lotnictwa, Warsaw, Poland) Instytut Lotnictwa, Prace (ISSN 0509-6669) no. 129-130 1992 p. 3-12. In Polish. refs
In the Aviation Institute a laboratory for tests of prospective aircraft board equipment systems was arranged. In this article a short description of the functions of the laboratory, its technical outfit and software as well as of the first modeling work was given. Author

A93-18774
PROGRESS TOWARDS COMMON STANDARDS FOR FLIGHT SIMULATOR QUALIFICATION
M. I. BLACKWOOD (Rediffusion Simulation, Ltd., Crawley, United Kingdom) *In* Flight simulation - European opportunities; Proceedings of the Conference, London, United Kingdom, May 1, 2, 1991 London Royal Aeronautical Society 1992 p. 11.1-11.10. refs
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The paper examines important issues involved in efforts toward common standards for flight simulator qualification, namely, test methodology, functional and subjective tests, and fly-by-wire considerations. The Approval Test Guide, which encompasses such items as basic simulator standards, functional and subjective tests, a glossary, and overall regulatory body philosophy as well as validation tests, is discussed. C.A.B.

A93-18776
A 'LOW-COST' FULL FLIGHT SIMULATOR FOR BASIC IFR TRAINING
M. BAARSPUL (Delft Univ. of Technology, Netherlands), CH. BRONNIMANN (Advanced Systems Engineering, Switzerland), and C. CONIJN (Hydraudyne Systems and Engineering, Boxtel, Netherlands) *In* Flight simulation - European opportunities; Proceedings of the Conference, London, United Kingdom, May 1, 2, 1991 London Royal Aeronautical Society 1992 p. 13.1-13.10. refs
Copyright
The present paper describes the 'low-cost' Seneca III full flight simulator, developed by ASE, Switzerland in cooperation with Hydraudyne (6 DOf motion system), and TUD (flight simulation software and 'Datcom-based' airplane mathematical model). The flight simulator hardware, consisting of a VME-BUS multi-processor link of about 60 microprocessors, a modified Seneca III cockpit with an electrical control loading system, an IVEX CGI-day/night visual system, and the 6 DOF hydrostatic motion system, is described in detail. The simulator software package consists of the aerodynamic, engine, mass properties, flight control system and landing gear models, based on the Seneca III geometry and inertia characteristics, and using 'Datcom' techniques. An attempt to validate the Datcom-based Seneca III flight simulator and its use for ab initio and recurrent training is presented. Author

A93-19077* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
VALIDATION OF VISION-BASED OBSTACLE DETECTION ALGORITHMS FOR LOW-ALTITUDE HELICOPTER FLIGHT
RAYMOND SUORSA and BANAVAR SRIDHAR (NASA, Ames Research Center, Moffett Field, CA) *In* Mobile robots V; Proceedings of the Meeting, Boston, MA, Nov. 8, 9, 1990 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 90-103. refs
Copyright
A validation facility being used at the NASA Ames Research Center is described which is aimed at testing vision based obstacle detection and range estimation algorithms suitable for low level helicopter flight. The facility is capable of processing hundreds of frames of calibrated multicamera 6 degree-of-freedom motion image sequencies, generating calibrated multicamera laboratory images using convenient window-based software, and viewing range estimation results from different algorithms along with truth data using powerful window-based visualization software. O.G.

A93-19148
DEVELOPMENT OF THE BOEING LOW SPEED AEROACOUSTIC FACILITY (LSAF)
RICHARD M. ALLEN and DAVID H. REED (Boeing Commercial Airplane Group, Seattle, WA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 187-195. refs
In recent years, noise testing requirements at Boeing have increasingly included the need for flight simulation as well as a quiet and anechoic background environment. This led to a design concept which added a low speed open jet test section to an existing anechoic chamber. The resulting Low Speed Aeroacoustic Facility (LSAF) features a 9 x 12-foot filleted contraction exit with flow capability from $M = .05$ to .25. Supply fans and motors are vibration isolated from the test section by massive foundations mounted on air springs. Fan noise is absorbed by a high performance duct silencer, installed in a reinforced concrete duct to minimize flanking path transmission of sound and vibration. Acoustic test capability includes traversing in-flow microphones, a traversing elliptical mirror for noise source location, and numerous stationary out-of-flow microphones. All data are analyzed on line and merged with performance data to provide complete final data within minutes of test run completion. Author

A93-19149* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE DESIGN OF TEST-SECTION INSERTS FOR HIGHER SPEED AEROACOUSTIC TESTING IN THE AMES 80- BY 120-FOOT WIND TUNNEL
PAUL T. SODERMAN and LARRY E. OLSON (NASA, Ames Research Center, Moffett Field, CA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 196-205. Previously announced in STAR as N92-28909 refs
An engineering feasibility study was made of aeroacoustic inserts designed for large-scale acoustic research on aircraft models in the 80- by 120 Foot Wind Tunnel at NASA Ames Research Center. The goal was to find test-section modifications that would allow improved aeroacoustic testing at airspeeds equal to and above the current 100 knots limit. Results indicate that the required maximum airspeed drives the design of a particular insert. Using goals of 200, 150, and 100 knots airspeed, the analysis led to a 30 x 60 ft open-jet test section, a 40 x 80 ft open-jet test section, and a 70 x 110 ft closed test section with enhanced wall lining respectively. The open-jet inserts would be composed of a nozzle, collector, diffuser, and acoustic wedges incorporated in the existing 80 x 120 ft test section. The closed test section

would be composed of approximately 5-ft acoustic wedges covered by a porous plate attached to the test-section walls of the existing 80 x 120. All designs would require a double row of acoustic vanes between the test section and fan drive to attenuate fan noise and, in the case of the open-jet designs, to control flow separation at the diffuser downstream end. The inserts would allow virtually anechoic acoustics studies of large helicopter models, jets and V/STOL aircraft models in simulated flight. Model scale studies would be necessary to optimize the aerodynamic and acoustic performance of any of the designs. Author

A93-19392
THE DYNAMIC CHARACTERISTICS OF A HIGH PRESSURE TURBINE STAGE IN A TRANSIENT WIND TUNNEL
A. G. SHEARD, A. J. DIETZ, and R. W. AINSWORTH (Oxford Univ., United Kingdom) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Rolls-Royce, PLC refs
(Contract SERC-GR/D/21189; SERC-GR/E/28062)
(ASME PAPER 92-GT-166)

A detailed analysis is presented of the dynamic characteristics of a new transient wind tunnel facility for the study of the time averaged and unsteady aerodynamics and heat transfer in a high-pressure turbine. The discussion covers the principal design features of the facility, mode of operation, the bearing system, rotor dynamics, natural frequency predictions and measurements, facility dynamics, field balancing, and vibration limits. Guidelines for running and balancing are presented. V.L.

A93-19511
THE VKI COMPRESSION TUBE ANNULAR CASCADE FACILITY CT3
C. H. SIEVERDING and T. ARTS (Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese, Belgium) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by SNECMA refs
(ASME PAPER 92-GT-336)

The purpose of this paper is to present the new transonic, annular facility developed at the von Karman Institute to investigate the aerodynamic heat transfer performances of real size advanced aero-engine and gas turbine components at correctly simulated operating conditions. The facility operates under the principle of an Isentropic Light Piston Compression Tube. Its definite advantage over classical blowdown wind tunnels is to independently model the freestream Mach and Reynolds numbers as well as the gas/wall/coolant temperature ratios. Its running time ranges between 0.1 and 1 s. The first part of the paper describes the design, the manufacturing and the installation of the different components of the wind tunnel and the test section. The second part deals with the different measurement techniques applied for aerodynamic and heat transfer measurements; it also describes some examples of the flow quality obtained in this new facility. Author

A93-19531
AN AUTOMATED FLOW LINE FOR GAS TURBINE BLADE REPAIR
DAVID B. DOLL (United Airlines, Maintenance Operations Div., San Francisco, CA) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992
(ASME PAPER 92-GT-367)

The expansion of United Airlines into a global airline has brought with it a substantial increase in the requirements for maintenance support. Existing operations for the repair of shrouded turbine blades were not structured to efficiently repair the increasing volume of unserviceable blades generated by the airline. The methodology of re-engineering the repair process for shrouded turbine blades in order to generate economies of scale is discussed. The design concepts for an integrated flow line with automated material handling and real time decision making are presented. Operation of the line including manual and automated inspection, automated grinding and welding and manual blending is described. Performance of the line is compared to the prior shop environment, and lessons learned in the accomplishment of the project are discussed. Author

A93-19659
THE STATE-OF-THE-ART OF NONDESTRUCTIVE EVALUATION OF MILITARY RUNWAYS
MARK ANDERSON (Carol D. Technologies, Inc., Panama City, FL) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11B; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 1909-1916. refs
Copyright

A multidisciplinary approach to nondestructive evaluation of pavements is presented, with emphasis on military runways. Consideration is given to the history of pavement evaluation, modern methods of pavement NDE, automated distress surveys, the falling weight deflectometer test, profilometry, radar, and wave propagation. It is argued that research is needed to automate data analysis and to increase the reliability of results of pavement evaluations. A data fusion system is needed to combine results from multiple tests to optimize the amount of information gained from data analysis. Achieving these goals will require a multidisciplinary approach, one that would utilize skills from many NDE specialty areas. P.D.

A93-20297* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYSIS, MODELLING AND SIMULATION OF THE LARGE-ANGLE MAGNETIC SUSPENSION TEST FIXTURE
COLIN P. BRITCHER, MEHRAN GHOFRANI (Old Dominion Univ., Norfolk, VA), and THOMAS C. BRITTON (Lockheed Engineering and Sciences Co., Hampton, VA) Jul. 1992 10 p. International Symposium on Magnetic Bearings, 3rd, Alexandria, VA, July 29-31, 1992, Paper refs
(Contract NAG1-1056)
Copyright

The large-angle magnetic suspension test fixture (LAMSTF) research project is described which is based on a sophisticated finite element computer program, VF/GFUN, for calculating magnetic fields. The LAMSTF design includes eddy current paths the effect of which on system dynamics is being studied to modify the system dynamic model and the digital controller. Linearized equations of motions have been developed for system modelling and analysis of controllers. O.G.

A93-20803
WALL-SIGNATURE METHODS FOR HIGH SPEED WIND TUNNEL WALL INTERFERENCE CORRECTIONS
QIWEI ZHANG (Nanjing Aeronautical Inst., China) Nanging Aeronautical Institute, Journal (ISSN 1000-1956) vol. 24, no. 5 Oct. 1992 p. 496-505. In Chinese. refs

Wall-signature methods for wall interference correction in high speed wind tunnel model tests is presented. The methods correct wall interference effects using the measured pressure distribution data near tunnel walls and the model force data. Without a knowledge of wall cross-flow properties, they can be used for various ventilated wall or solid wall wind tunnels. Hundreds of test cases including several models in various different tunnels (solid wall, streamline wall, perforated wall, slotted wall) are corrected by these methods. The test Mach number range is 0.5 to 0.9. The Reynolds number range is 2 x 10 exp 6 to 1 x 10 exp 7. The corrected results are compared with the foreign newest corrections and Navier-Stokes free-air solutions. The correctness and practicality of these methods are verified. Author

A93-20808
FINE CONTROL OF MACH NUMBER IN SUBSONIC WIND TUNNEL
BAISEN RONG, JIAN LU, and NING JIN (Nanjing Aeronautical

Inst., China) Nanjing Aeronautical Institute, Journal (ISSN 1000-1956) vol. 24, no. 5 Oct. 1992 p. 541-545. In Chinese.

A method for finely adjusting Mach number in a subsonic tunnel is investigated, and data used to control Mach number are provided. The experimental results show that the method takes a short time to implement and is highly accurate. P.D.

A93-21833
DUAL TRANSVERSE INJECTION OF H2 GAS INTO MACH 1.8 FLOWS AT UNIVERSITY KOMABA WIND TUNNEL
TOSHIO NAGASHIMA, MICHIKATA KONO, MASARU HIRATA, and YOSHIMICHI TANIDA (Tokyo Univ., Japan) Tokyo, University, Faculty of Engineering, Journal, Series B (ISSN 0563-7937) vol. 41, no. 3 March 1992 p. 369-380.
(Contract MOESC-B02452089)

Experimental studies on the wave interaction and flow mixing/diffusion, when H2 fuel gas is injected into supersonic air flows of Mach number 1.8, have been described. Comparison between the test results by using the single and dual injectors shows that a prior injection upstream of the main H2 gas injection may be beneficial for optimization with respect to total pressure loss and ignition of hydrogen-air mixtures. All the experiments have been carried out at University Komaba wind tunnel facility, which is rather 'old' but contributes well to the 'new' era RAM/SCRAM jet propulsion system development. Author

A93-21900
DEVELOPMENT OF ULTRA-HYPERSONIC SHOCK TUNNEL FOR AERODYNAMICS TEST
KIRK HANAWA, YASUHIRO TOMIOKA, MUTSUO KOTAKE, TADASHI MIKAMI, and YASUHIKO TANAKA Ishikawajima-Harima Engineering Review (ISSN 0578-7904) vol. 32, no. 5 Sept. 1992 p. 367-372. In Japanese. refs

A Shock Tunnel was constructed for use in the development test for ultrahypersonic vehicles. The system uses a free piston in a shock tube accelerated by high pressure. The high-temperature and high-pressure air generated downstream of the piston breaks the membrane at the shock tube end. This provides an ultrahypersonic air flow with a shock wave into a vacuum chamber through a conical nozzle. In the aerospace field, large test facilities of this type are planned at research laboratories. This paper outlines the design, manufacturing, and operational characteristics and presents test results obtained at the National Defense Academy. Author

A93-22174
ICE PREDICTION SYSTEMS FOR RUNWAYS
T. HAAVASOJA and H. J. MELAMA (Vaisala Oy, Helsinki, Finland) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 345-350. Copyright

The ICECAST ice-prediction system for airport use is described. A typical runway ice prediction system consists of field stations, one central station, and workstations. In the ICECAST system the central station can also be used as a workstation. The surface condition sensor is thermally passive and based on capacitive and electrochemical measurement. The capacitive sensing allows detection of so-called black ice, whose electrical conductivity is too poor to be detectable by electrochemical means. The system is capable of distinguishing between rain, sleet, and snow. The sensor separately follows liquid and frozen precipitation intensities as well as accumulation of water content and snow height. Warnings and alarms from the field stations can be configured to be passed through a pager system. It is also possible to generate special alarms at the workstation level. P.D.

A93-22311#
HYPERVELOCITY SCRAMJET CAPABILITIES OF THE T5 FREE-PISTON TUNNEL AT CALTECH
JAMES A. DAVIS, ROGER L. CAMPBELL, JOHN A. MEDLEY (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA), and HANS G. HORNUNG (California Inst. of Technology, Pasadena) Dec. 1992 12 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992
(AIAA PAPER 92-5037) Copyright

A review is presented of the development and initial operation of the California Institute of Technology's T5 Free-Piston Shock Tunnel. The objective in building this facility was to generate high enthalpy flow at sufficiently high densities and velocities to adequately simulate the scramjet combustion processes. The facility is now operating to explore a number of NASP related and diverse hypersonic technologies. R.E.P.

A93-22317#
POWER GENERATION SOURCE FOR AN ELECTROTHERMAL HYPERSONIC WIND TUNNEL
MARTIN SUMMERFIELD (Princeton Combustion Research Labs., Inc., Monmouth Junction, NJ) Dec. 1992 7 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5045) Copyright

The design of a dc electric power generator that would feed the cartridge of an electrothermal wind tunnel with 7.1 KV and 70.6 KA, making an electric power of 500 MW, for a duration of 0.3 seconds is presented. This is accomplished with a system that drives a conductive piston through a magnetic field, the push being furnished by gas pressure. Details of the design including the electromagnet, the piston, and the electrodes, are provided with drawings showing how the system is to be constructed. R.E.P.

A93-22695#
THE AIR FORCE FLIGHT TEST CENTER ARTIFICIAL ICING AND RAIN TESTING CAPABILITY UPGRADE PROGRAM
RUSSELL A. ASHENDEN (USAF, Mechanical Systems Branch, Edwards AFB, CA) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993
(AIAA PAPER 93-0295)

A tanker upgrade program, initiated in 1987 by the U.S. Air Force Flight Test Center for improving the artificial icing and rain testing capability of a modified tanker aircraft S/N 55-315A used for in-flight testing, included modifying the engine bleed air and water supply systems and designing a new spray array. Other changes were incorporated, such as adding the Laser Distance Measuring System and a water system purge capability. Results of air worthiness and operational testing showed that the tanker upgrade program has greatly improved the operational capabilities of the tanker aircraft, such as making possible cold weather operations, longer test flights, and accurate test vehicle tracking. I.S.

A93-22697#
ICING TESTING OF A LARGE FULL-SCALE INLET AT THE ARNOLD ENGINEERING DEVELOPMENT CENTER
C. S. BARTLETT and WILLIAM J. PHARES (Sverdrup Technology, Inc., Arnold AFB, TN) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0299)

A review is presented of the icing simulation methods employed at AEDC, the test facility as configured to perform the icing test, including descriptions of the water spray system, engine simulator, test cell ducting, and test cell video systems. The CFD research performed to position the inlet relative to the free-jet nozzle discharge to obtain acceptable inlet cowl surface static-to-total pressure ratios are described. The experimental data obtained to verify the proper positioning of the inlet are given. R.E.P.

A93-23031*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
COMPARISON OF PREDICTIONS WITH MEASUREMENTS FOR A QUIET SUPERSONIC TUNNEL
LYNDELL S. KING (NASA, Ames Research Center, Moffett Field, CA) and ANTHONY DEMETRIADES (Montana State Univ.,

Bozeman) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0344) Copyright

Navier-Stokes and boundary layer calculations were made to study the mean flow through the Montana State University Mach 3 supersonic wind tunnel. Two-dimensional results along the nozzle surface are found to be in good agreement with experiment. For the sidewalls a 3D solution was necessary because of a skew-induced secondary flow that produced significant crossflows in the sidewall boundary layer and thickening of the boundary layer near the sidewall centerline. Boundary layer stability calculations revealed Goertler instabilities in the nozzle producing N factors up to 6. Preliminary results for the crossflow instability on the tunnel sidewall show a maximum N factor of about 2.5 under test conditions for which laminar flow was observed experimentally. O.G.

A93-23034#
UPGRADE OF BALLISTIC RANGE FACILITIES AT AEDC - TWO-THIRDS COMPLETE
A. J. CABLE (Calspan Corp., Arnold AFB, TN) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993
(AIAA PAPER 93-0349)

This paper discusses the planned upgrading of the ballistic range facilities at AEDC. Upon completion of the upgrade, the AEDC Hypervelocity Testing Complex will consist of: (1) a large 3.3-in. bore two-stage light-gas launcher providing soft launch of models into the existing 930-ft-long Range G; (2) a 2.5-in. bore two-stage light-gas launcher with the same performance as the existing Range G launcher, launching models into a dedicated Impact Range; and (3) a high-performance free-piston shock tunnel capable of stagnation pressures of 10,000 atm and stagnation temperatures of 10,000 K. Author

A93-23035*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
INCREASE IN STAGNATION PRESSURE AND ENTHALPY IN SHOCK TUNNELS
DAVID W. BOGDANOFF and JEAN-LUC CAMBIER (Eloret Inst., Palo Alto, CA) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NCC2-487)
(AIAA PAPER 93-0350)

A new technique based on the insertion of a converging section in the driven tube is described which is capable of producing substantial increases in both reservoir pressure and enthalpy. A 1D inviscid full kinetics code is used to study a number of different locations and shapes for the converging driven tube section. For driven tube diameter reductions of factors of 2 and 3, the reservoir pressure is found to increase by factors of 2.1 and 3.2, respectively, and the enthalpy is found to simultaneously increase by factors of 1.5 and 2.1, respectively. O.G.

A93-23036#
CHARACTERIZATION OF THE PERFORMANCE OF SHOCK-TUBE WIND TUNNELS
LEON H. SCHINDEL (U.S. Navy, Naval Surface Warfare Center, Silver Spring, MD) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0351)

Shock tubes have often been used in hypersonic wind tunnel test facilities. Attention is presently given to a number of variations that have been proposed for the heat/pressure driver for the shock; these include an expansion tube, reflected-shock operation, multishock operation, and a free-piston compressor. The parameters of interest are the test Mach number and corresponding stagnation pressure and temperature. O.C.

A93-23037#
QUASI-ONE-DIMENSIONAL MODELLING OF FREE-PISTON SHOCK TUNNELS
P. A. JACOBS (WBM-Stalker, Pty., Ltd., Brisbane, Australia) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0352) Copyright

A Lagrangian formulation for the quasi-one-dimensional modeling of free-piston driven shock tunnels is described. Three simulations of particular conditions for the T4 shock tunnel are then presented and compared with experimental measurements. The simulations provide very good estimates for both the shock speed and the nozzle-supply pressure obtained after shock reflection and also provide detailed information on the gas-dynamic processes over the full length of the facility. This detailed information may be used to identify some of the causes for observed variations in nozzle supply pressure. Author

A93-23038#
FLOW QUALITY IMPROVEMENT IN A HIGH SPEED BLOWDOWN WIND TUNNEL
PAUL G. C. HERRING and JOE A. SMITH (British Aerospace, PLC, Sowerby Research Centre, Bristol, United Kingdom) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by CEC refs
(AIAA PAPER 93-0353) Copyright

The paper describes how the flow quality in a Mach 6 supersonic blowdown wind tunnel was improved by replacing the flexible nozzle linear plates. The original liner plates had become damaged when they were stressed beyond their elastic limit, a microswitch controlled stress limiting system having failed. The resulting kinks in the liner produced severe flow disturbances in the working section of the tunnel which resulted in data of an unacceptable quality being produced. In order to prevent similar damage occurring to the new liners, a more reliable stress limiting system has been installed. Details of new monitoring system are given. Examples of working section flowfield surveys and aerodynamic data obtained before and after liner replacement show the extent of improvement to the flow quality. The paper also presents some data obtained from a recent test series on a simple wing-body research model. Author

A93-23040#
AN OPTICAL COMPARISON OF WALL AND AXIAL INJECTION FOR HIGH ENTHALPY REACTING SCRAMJET FLOWS
T. E. PARKER, M. G. ALLEN, R. R. FOUTTER, D. M. SONNENFROH, and W. T. RAWLINS (Physical Sciences, Inc., Andover, MA) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract F33615-91-C-2204)
(AIAA PAPER 93-0357) Copyright

A shock tunnel for the generation of mixing and combusting high-enthalpy flows similar to those encountered in scramjet engines has been used together with nonintrusive (planar laser-induced fluorescence) optical diagnostics to monitor the performance of two different injector configurations. The results obtained indicate that a velocity-matched axial injection system produced a fuel jet that lifted off the floor of the duct; mixing was enhanced in this system with the introduction of a velocity mismatch. O.C.

A93-23297*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AN INTEGRATED KNOWLEDGE SYSTEM FOR WIND TUNNEL TESTING - PROJECT ENGINEERS' INTELLIGENT ASSISTANT
CHING F. LO, GEORGE Z. SHI (Tennessee Univ., Tullahoma), W. A. HOYT (ERC, Inc., Tullahoma, TN), and FRANK W. STEINLE, JR. (NASA, Ames Research Center, Moffett Field, CA) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS2-12965; NAS2-13203)
(AIAA PAPER 93-0560) Copyright

The Project Engineers' Intelligent Assistant (PEIA) is an integrated knowledge system developed using artificial intelligence technology, including hypertext, expert systems, and dynamic user

interfaces. This system integrates documents, engineering codes, databases, and knowledge from domain experts into an enriched hypermedia environment and was designed to assist project engineers in planning and conducting wind tunnel tests. PEIA is a modular system which consists of an intelligent user-interface, seven modules and an integrated tool facility. Hypermedia technology is discussed and the seven PEIA modules are described. System maintenance and updating is very easy due to the modular structure and the integrated tool facility provides user access to commercial software shells for documentation, reporting, or database updating. PEIA is expected to provide project engineers with technical information, increase efficiency and productivity, and provide a realistic tool for personnel training. A.O.

A93-23510* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

FLIGHT SIMULATOR FIDELITY ASSESSMENT IN A ROTORCRAFT LATERAL TRANSLATION MANEUVER

R. A. HESS, T. MALSBURY (California Univ., Davis), and A. ATENCIO, JR. (NASA, Ames Research Center, Moffett Field, CA) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 1 Jan.-Feb. 1993 p. 79-85. Previously cited in issue 23, p. 4072, Accession no. A92-55348 refs
(Contract NAG2-482)
Copyright

A93-23698*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

LIQUID WATER CONTENT MEASUREMENTS USING THE PHASE DOPPLER PARTICLE ANALYZER IN THE NASA LEWIS ICING RESEARCH TUNNEL

R. C. RUDOFF, E. J. BACHALO, W. D. BACHALO (Aerometrics, Inc., Sunnyvale, CA), and J. R. OLDENBURG (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 17 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAS3-25653)
(AIAA PAPER 93-0298) Copyright

The performance of a Phase Doppler Particle Analyzer (PDPA) based icing probe suitable for use in icing tunnels and airborne applications is assessed. The instrument is shown to accurately and repeatably measure liquid water content (LWC) to within better than 20 percent of the nominal expected value in the NASA Lewis IRT. This was seen to be true over a wide range of tunnel operating conditions. The principles used by the PDPA for MVD and LWC determination are discussed. Calibration curves for the IRT median volume diameter are also determined and compared to the existing calibration determined via the PMS instruments. As has been shown in previous work, the PDPA is quite repeatable. The results are typically 3 to 5 microns smaller than the existing calibrations for a given run condition. Reasons for these differences are also discussed. Author

N93-15790*# *National Aeronautics and Space Administration.* Langley Research Center, Hampton, VA.

TECHNOLOGY BENEFITS AND GROUND TEST FACILITIES FOR HIGH-SPEED CIVIL TRANSPORT DEVELOPMENT

MATTHEW M. WINSTON, ELWOOD M. SHIELDS (Lockheed Engineering and Sciences Co., Hampton, VA.), and SHELBY J. MORRIS, JR. Dec. 1992 29 p
(Contract RTOP 505-69-20-01)
(NASA-TM-107670; NAS 1.15:107670) Avail: CASI HC A03/MF A01

The advanced technology base necessary for successful twenty-first century High-Speed Civil Transport (HSCT) aircraft will require extensive ground testing in aerodynamics, propulsion, acoustics, structures, materials, and other disciplines. This paper analyzes the benefits of advanced technology application to HSCT concepts, addresses the adequacy of existing groundbased test facilities, and explores the need for new facilities required to support HSCT development. A substantial amount of HSCT-related ground testing can be accomplished in existing facilities. The HSCT development effort could also benefit significantly from some new facilities initially conceived for testing in other aeronautical research areas. A new structures testing facility is identified as critically needed to insure timely technology maturation. Author

N93-15998# Federal Aviation Administration, Washington, DC. Systems Research and Development Service.

UNIFIED AIRPORT PAVEMENT DESIGN AND ANALYSIS CONCEPTS WORKSHOPS

Jul. 1992 579 p Workshops held in Cambridge, MA, 16-17 Jul. 1991
(AD-A257157; DOT/FAA/RD-92/17) Avail: CASI HC A25/MF A06

This publication outlines the proceedings of a workshop held in July 1991 at Cambridge, MA. The workshop provided a forum for leading pavement engineers, researchers and materials scientists to present concepts for the formulation of a unified mechanistic methodology for the analysis and design of pavements serving civil aircraft. The need developed from industry's requests for adequate methods to design, analyze and predict performance of pavements serving more demanding aircraft. The publication contains essential elements of papers and reports presented at the workshop. The general agreement was that, given the prevailing state of the art in computer capability, the requirements for increased capacity through more frequent passes and heavier aircraft, and the development of new man-made construction materials, a more realistic and cost-beneficial approach to pavement analysis and design could be accomplished through the use of discrete material elements, faithful representation of actual material behavior and geometry, and dynamic interaction with rates of loading from any gear configuration. The belief was that computer programs capable to perform the task already exist in other areas of engineering mechanics and that they could be tailored for pavement applications. The papers presented would substitute current methods based on empirical data and broad theoretical assumptions with a generally applicable mechanistic approach. The suggested approach would obviate anomalies that result when current methods are applied to certain cross-section configurations. GRA

N93-16309# Federal Aviation Administration, Washington, DC.

UNIFIED AIRPORT DESIGN AND ANALYSIS CONCEPTS WORKSHOP

Jul. 1992 542 p Workshop held in Cambridge, MA sponsored by the Federal Aviation Administration 16-17 Ju l. 1991 Original contains color illustrations
(Contract GWA 89-TA)
(DOT/FAA/RD-92/17) Avail: CASI HC A23/MF A04; 9 functional color pages

The proceedings of a workshop held in July 1991 at Cambridge, MA are outlined. The workshop provided a forum for leading pavement engineers, researchers, and materials scientists to present concepts for the formulation of a unified mechanistic methodology for the analysis and design of pavements serving civil aircraft. The need developed from industry's requests for adequate methods to design, analyze, and predict performance of pavements serving more demanding aircraft. Essential elements of papers and reports presented at the workshop are included.

N93-16310# Arizona State Univ., Flagstaff. Dept. of Civil Engineering.

STATE OF THE ART OF AIRPORT PAVEMENT ANALYSIS AND DESIGN

J. ZANIEWSKI *In its* Unified Airport Pavement Design and Analysis Concepts Workshop p 1-51 Jul. 1992
Avail: CASI HC A03/MF A04; 9 functional color pages

Due to the difficulty of the airport pavement analysis process, design methods have evolved in an empirical manner. While these methods produced workable designs, they have several shortcomings. There have been significant developments in the areas of engineering mechanics and materials evaluation that can provide the foundation for the development of improved airport pavement design procedures. The purpose of this report is to summarize the state of the art in airport pavement analysis models.

This task does not have a clear boundary. There are models that have been used for many years for pavement design. There are also models that are applied only by engineers that are on the leading edge of technology for the design of pavement structures. Other models have been proposed by researchers but have not been used extensively for airport pavement analysis. Finally, there are models that have been developed in other engineering fields that can be applied to the analysis of airport pavements. Author

N93-16311# Illinois Univ., Urbana.
DEVELOPMENT OF USER GUIDELINES FOR A THREE-DIMENSIONAL FINITE ELEMENT PAVEMENT MODEL
A. M. IOANNIDES and J. P. DONNELLY (Wiss, Janney, Elstner and Associates, Inc., Northbrook, IL.) *In its* Unified Airport Pavement Design and Analysis Concepts Workshop p 52-85 Jul. 1992
Avail: CASI HC A03/MF A04; 9 functional color pages

A multi-component project, sponsored by the U.S. Air Force Office of Scientific Research (AFOSR), has recently examined current computerized analysis techniques for slabs-on-grade. The final stage of those investigations involved the use of an existing three-dimensional finite element model, which was adapted to provide a more realistic representation of a pavement system. One of the conclusions of that study was that a three-dimensional finite element program will be 'indispensible in future efforts to establish the elusive 'unified' approach (to pavement design) and to develop a generalized mechanistic design procedure.' The Federal Aviation Administration (FAA) initiative for the development of a 'Unified Pavement Theory' has provided new impetus for considering the three-dimensional finite element approach and has renewed interest in studies for the development of user guidelines for this sophisticated technique. The results of more than 100 three-dimensional finite element runs conducted to develop such user guidelines during the aforementioned AFOSR study are reported in detail. Research is reported of the slab-on-grade problem. Findings presented provide an essential guide for the effective utilization of the three-dimensional finite element approach, and are described herein to facilitate development efforts under the FAA initiative, and perhaps eliminate the need for conducting such preliminary and time-consuming studies again. Author

N93-16312# Texas A&M Univ., College Station.
MICRO MECHANICAL BEHAVIOR OF PAVEMENTS
R. LYTTON *In its* Unified Airport Pavement Design and Analysis Concepts Workshop p 86-123 Jul. 1992
Avail: CASI HC A03/MF A04; 9 functional color pages

A brief summary of the types of distress, the types of material properties, and which types of material properties are needed to describe each type of distress in each airport pavement layer are presented. Constitutive equations that are appropriate for these material properties are listed in increasing order of complexity, with the simpler ones being preferred for microcomputer applications. Illustrations of materials characterizations are presented covering a simple way of representing the damage done to a material by microcracking, the formulation of elastic dilatancy, and the determination of material properties for a hypoelastic base course material. These illustrations demonstrate the kind of materials characterization that will be required to permit accurate predictions of the rate of appearance of pavement distress and FOD potential. It is envisioned that all of these materials characterizations will be implemented in a three-dimensional (3-D) finite element (FE) program and thus the materials properties must have two principal attributes: (1) they must be capable of being determined from laboratory tests, and (2) they must be capable of being represented in a finite element program and lead to stable convergence in an iterative computational scheme. Author

N93-16313# Pennsylvania State Univ., University Park.
THERMOVISCOELASTIC ANALYSIS OF PAVEMENTS
S. K. REDDY and M. G. SHARMA *In its* Unified Airport Pavement Design and Analysis Concepts Workshop p 124-168 Jul. 1992
Avail: CASI HC A03/MF A04; 9 functional color pages

In design and rehabilitation of pavements, it is necessary to evaluate damage due to traffic loading and environmental conditions. Damage in multilayered asphalt pavements could be of various types, namely transverse and longitudinal cracking, delamination, rutting, and degradation of material properties. Computation of stresses and strains is essential for the evaluation of damage. Analysis of stresses due to the effect of temperature was considered. The stresses in the surface layer could be severe, as it is subjected to a wider range of temperatures compared to the underlying layers. Also, since the asphaltic top layer is a rheological material, the stresses are functions of both loading and time. These stresses could cause damage due to cracking, especially at low temperatures during winter or due to thermal fatigue as the pavement is subjected to cyclic variation of temperature. Also, delamination can occur due to the multilayered nature of pavements and the resulting mismatch in thermal properties of adjacent layers. Since pavements are layered systems, the temperature variations give rise to complex stresses in the system which can be evaluated only through numerical methods such as finite element analysis. Although a three-dimensional analysis is desirable, it is complex and time consuming. Hence, as a primary step, two-dimensional analyses with and without temperature gradients was performed in the investigation. In addition, the effect of physical hardening of asphalt layer on thermal stress was evaluated. Author

N93-16314# Foster-Miller Associates, Inc., Waltham, MA.
FAA UNIFIED PAVEMENT ANALYSIS 3-D FINITE ELEMENT METHOD
S. J. KOKKINS *In its* Unified Airport Pavement Design and Analysis Concepts Workshop p 169-232 Jul. 1992
Avail: CASI HC A04/MF A04; 9 functional color pages

The limitations of the existing pavement analysis and design methods do not yet provide a model capable of accurately predicting the useful life of airport pavements. This includes the prediction of pavement performance in terms of distress as a function of traffic and environmental loadings, and their mutual interaction. The eventual model must be sensitive to the initial material properties and must respond to the daily, seasonal, and aging variations in these properties. Primarily, the unified theory must provide the theoretical foundation for the prediction of pavement displacement and deflection basin profile under different types of aircraft as well as under different types of nondestructive testing devices. The pavement evaluation methodology should include the ability to determine pavement properties from the results of nondestructive testing. This program demonstrates that 3-D finite element (FE) structural modeling is an effective and practical method for evaluating the response of airport pavement systems, and that it can form the basis of the unified pavement analysis method. Although the work so far has used existing analytical tools, similar methods tailored to the needs of airport pavements, together with appropriate constitutive material relationships and modern computer graphics can be integrated into a unified pavement analysis system using 3-D FE modeling. Accomplishments, described in this report, include (1) demonstration and verification of the solution of classical pavement problems using 3-D FE analysis; (2) formulation and solution of a range of practical aircraft load and airport pavement configurations, showing the capabilities of these methods; (3) visualization of the results using 3-D color graphics; (4) evaluation of two forms of nonlinear soil response; and (5) developments in the constitutive material modeling relationships for pavement materials, suitable for inclusion in FE solution procedures. Author

N93-16315# Battelle Columbus Labs., OH.
FEDERAL AVIATION ADMINISTRATION PAVEMENT MODELING
T. FORTE, K. MAJIZADEH, J. KENNEDY, J. HADDEN, T. WHITE, ANDREW SLUZ, and ASTON MCLAUGHLIN *In its* Unified Airport Pavement Design and Analysis Concepts Workshop p 233-313

Jul. 1992 Original contains color illustrations
Avail: CASI HC A05/MF A04; 9 functional color pages

The Federal Aviation Administration (FAA) of the U.S. Department of Transportation (DOT) has recognized the significant limitations of current pavement design and analysis techniques. As a result, the FAA has initiated a multi-year program to develop a model capable of predicting accurately the useful life of airport pavements. This model, a Unified Pavement Design and Analysis Program (UPDAP), will be capable of predicting stresses, deformations, and performance in any airport pavement system for nearly any pavement configuration, material, and operating/environmental condition. It will be based on mechanistic principles, rather than on empirically derived relationships, and will provide pavement engineers with a comprehensive, flexible analytical tool for efficient design or evaluation of new and existing pavements. For existing pavements, the UPDAP will be capable of integrating inspection data to establish the current state of the pavement, and to assess proposed rehabilitation actions. The scope of the task was the development and justification of a concept for the UPDAP. It includes a recommended concept for the UPDAP, an in-depth presentation of a recommended methodology for pavement constitutive modeling, recommendations for pavement structural modeling, damage modeling considerations, a discussion of the critical issues associated with field testing of pavement systems, and conclusions and recommendations for further study. Author

N93-16316# Resource International, Inc., Columbus, OH.
STATE OF THE ART REVIEW OF RUTTING AND CRACKING INPAVEMENTS
K. MAJIDZADEH (Ohio State Univ., Columbus.), C. L. SARAF, S. MESAROVIC, and G. J. ILVES *In its* Unified Airport Pavement Design and Analysis Concepts Workshop p 314-391 Jul. 1992
Avail: CASI HC A05/MF A04; 9 functional color pages

Several available computer methods and models to predict pavement rutting are reviewed. All these programs were originally developed for highway pavement distress prediction and/or analysis. Thus, some modifications will be needed considering the substantially higher tire pressures and wheel loads to be expected from aircraft. Careful considerations of asphalt concrete rutting prediction models is necessary in view of the inherently high tire pressures (over 300 psi) (2 MPa) applied by some aircraft. It is estimated that plastic yield of asphalt concrete occurs at this high pressure which is well above the threshold pressure used for permanent deformation characterization of asphalt concrete mixtures for highway applications. Several rutting models based on empirical relationships are discussed. Fracture mechanics can be used to analyze cracking in pavements. The discussion on fracture mechanics is divided into the following topics: (1) application of fracture mechanics to pavement materials; (2) application of fracture mechanics to analyze pavements; (3) effect of mix variables on the fatigue parameters; (4) extension of cracking analysis to include non-linear behavior of materials; and (5) considerations for the statistical nature of the pavement system and its components. Author

N93-16317# ERES Consultants, Inc., Savoy, IL.
DEVELOPMENT OF A UNIFIED AIRPORT PAVEMENT ANALYSIS AND DESIGN SYSTEM
E. OWUSU-ANTWI, M. G. SHARMA (Pennsylvania State Univ., University Park.), R. H. DODDS (Illinois Univ. at Urbana-Champaign, Savoy.), P. D. HILTON (Little, Arthur D., Inc., Cambridge, MA), M. I. DARTER (Illinois Univ. at Urbana-Champaign, Savoy.), and H. T. YU (Little, Arthur D., Inc., Cambridge, MA) *In its* Unified Airport Pavement Design and Analysis Concepts Workshop p 392-445 Jul. 1992
Avail: CASI HC A03/MF A04; 9 functional color pages

Aircraft weight and number of operations at our nation's airports are expected to continue to increase into the foreseeable future. This will place a heavy burden on the pavement facilities at U.S. airports, which if not adequately designed, will result in significant deterioration. To insure that airport pavement facilities will be capable of carrying these increased traffic levels, the Federal Aviation Administration (FAA), through the Volpe National Transportation System Center (TSC), is sponsoring research on the development of a unified pavement model for the analysis and design of airport pavements. The goal of this program is to make the technological leap that will allow a more reliable analysis and design of all types of airport pavements, since current design procedures have many serious deficiencies. This paper describes the concepts proposed for the development of such a unified airport pavement analysis and design system. The central component of the system is a 3-dimensional finite element analysis (FEA) based primary response model, applicable to the nonlinear analysis of all types of airport pavements. A unique solution procedure is proposed that will allow the realistic solution of complex airport problems on desktop computers. This procedure is expected to reduce memory requirements and increase processing speed by a factor of between 5 and 10, in comparison to currently available 3-dimensional codes, and thus reduce computation costs. Another major portion of the proposed system is the material constitutive models proposed for incorporation in the primary response model. Incremental constitutive models for the major classes of airport pavement materials, that will allow a stepwise addition of 'memory' variables or parameters to basic constitutive models to accurately describe the physical behavior of increasing complex materials, will be incorporated into the primary response model. A database of the outputs of nodal displacements, stresses, strains, and local damage measures generated by the primary response model will be used in a damage analysis, the results of which can be used to predict key distress types. This will provide for greater design reliability and cost-effective pavement design. Author

N93-16318# SRI International Corp., Menlo Park, CA.
UNIFIED AIRPORT PAVEMENT DESIGN PROCEDURE
L. SEAMAN, J. W. SIMONS, D. A. SHOCKEY, R. F. CARMICHAEL, III (ARE, Inc., Austin, TX.), and B. F. MCCULLOUGH (ARE, Inc., Austin, TX.) *In its* Unified Airport Pavement Design and Analysis Concepts Workshop p 446-537 Jul. 1992 Original contains color illustrations
Avail: CASI HC A05/MF A04; 9 functional color pages

Initial steps were taken toward developing a mechanistic approach to the design of airport pavement structures and carried through sufficiently to provide proof of concept. At the start of this project, the major elements that were unavailable were determined to be a method for lifetime prediction and material models to describe fatigue cracking and rutting. During this project, we have developed initial versions of all three of these elements. We have developed a method for predicting pavement lifetimes using three-dimensional finite element codes and the material models. This prediction procedure led us to requirements on the nature and accuracy of the material models. The material model for fatigue cracking is a micromechanical extension of an available fatigue model used for metals and other materials. This mechanistic model is based on the presence of flaws in the material that are grown during periods of tensile stress. With sufficient growth, these flaws become the large cracks that represent destruction of both Portland cement and asphalt concrete pavement. The fatigue model was incorporated into an SRI multiple-plane plasticity model to be able to represent the serious anisotropy that develops during cracking. This combined model, in a computer subroutine, was included with the three-dimensional finite element code DYNA3D, and simulations were made for an aircraft wheel gear rolling over a pavement. Then a lifetime prediction was made based on fatigue cracking in the base of the pavement. The rutting model was developed based on an examination of the observed (and unusual) viscoelastic, dilatant, and viscoplastic behavior of asphalt concrete pavement. The model has components that represent each of these aspects, although rutting probably depends primarily on the permanent deformation caused by the viscoplastic behavior. The model appears to reproduce laboratory data satisfactorily. We have not completed implementation of the model into a computer subroutine appropriate for combining with DYNA3D, so we could not perform simulations of wheel loading tests. Through this project we have developed a lifetime prediction procedure, a material

model for fatigue damage, and a model for rutting. We have shown that each appears to represent field and/or laboratory conditions, although we do not have complete quantitative verifications. However, we feel that we have shown that each of these major new aspects of the pavement design procedure is feasible. Because the concept of a unified pavement theory has been proved in this initial project, we recommend continuation of the effort to develop a mechanistic design procedure for pavements. Author

N93-16319# Department of Transportation, Cambridge, MA.
THREE-DIMENSIONAL STRESS ANALYSIS OF MULTILAYERED AIRPORT PAVEMENTS: INTEGRAL TRANSFORM APPROACH
G. SAMAVEDAM *In its* Unified Airport Pavement Design and Analysis Concepts Workshop p 538-565 Jul. 1992
Avail: CASI HC A03/MF A04; 9 functional color pages

With the increased traffic of current aircraft and larger and heavier aircraft likely to be introduced in the near future, the performance demands on existing airport pavements will be significantly higher than those envisioned a few decades ago. The maintenance and repair of the existing pavements and potential new designs in the future must take full advantage of advanced theories on the subject. At present, several advanced concepts are available in the general field of structural mechanics which are not fully exploited for the pavement analysis. There are several reasons for the current state of art in the pavement being not on a part with modern developments in structural mechanics. One of the reasons is that the airport pavement structures were there long before the advanced computer models/concepts emerged. A large amount of work had already been expended in testing and empirical correlations of the test data. A primary reason, however, is due to the fact that no systematic investigations have been carried out on the validity and applicability of the advanced structural mechanics concepts to the pavement structure. Such investigations form a major part of the research being initiated by Volpe National Transportation Systems Center/Federal Aviation Administration (VNTSC/FAA), with the ultimate aim of synthesizing into an advanced unified treatment of all types of pavements. This report presents ideal characteristics of the structural and material modeling for pavement and deals specifically in an approach for three-dimensional stress analysis of the pavement structure. Author

N93-16468# Manchester Univ. (England). Aeronautical Engineering Group.
DESIGN OF A NOZZLE FOR A HYPERSONIC WIND TUNNEL
A. H. TAJFAR and I. M. HALL 1991 98 p
(AERO-REPT-9113; ETN-92-92779) Avail: CASI HC A05/MF A02

The design of two dimensional wind tunnel nozzles, with test section Mach numbers up to Mach 10, for supersonic and hypersonic testing is described. The design starts with the transonic region, the throat section, using previously obtained solutions. The method of characteristics was used for the design of the supersonic part of the nozzle. In the supersonic part, a smooth Mach number distribution was specified along the axis of symmetry. Using a cubic variation ensured smooth acceleration was successful for low supersonic Mach numbers, however it failed to produce acceptable results for higher Mach numbers. A new method for obtaining a smooth, and suitable, Mach number distribution along the axis of symmetry was developed, based on a smooth 'area variation' along the axis. This approach was successful for the higher Mach number hypersonic range. Focus is on air nozzles with gamma equals 1.4 but the effects of different values of gamma were studied. The main interest was in hypersonic nozzles for which the Reynolds number was likely to be low enough for the boundary layer to be laminar. Therefore the boundary layer growth was calculated based on the methods of Luxton and Young. Two methods of calculation were tried. The modified, or improved, version was used. ESA

N93-16695*# Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics.
APPROACHES TO CONTROL OF THE LARGE ANGLE MAGNETIC SUSPENSION TEST FIXTURE Annual Progress Report, 1 Nov. 1991 - 31 Oct. 1992
MEHRAN GHOFRANI and COLIN P. BRITCHER Dec. 1992 126 p
(Contract NAG1-1056)
(NASA-CR-191890; NAS 1.26:191890) Avail: CASI HC A07/MF A02

The Large Angle Magnetic Suspension Test Fixture is a five degree-of-freedom system, developed and built at NASA Langley Research Center. It is intended for study of control techniques in magnetic suspension systems with large angular capabilities. In this study, steps have been taken to prove the system in practice, using the existing hardware. A classical control approach, using dual phase advance compensators, is applied in simulation and hardware. A single decoupled degree-of-freedom of the system is stabilized and controlled in simulation. The procedure is then employed for all five degrees-of-freedom. The design and implementation of an analog and a digital controller are described. Results from simulation and the actual system are compared and analyzed. The ability to the system to sustain suspension over a large angular range has been proven in hardware. Author

N93-16753*# National Aeronautics and Space Administration. Flight Research Center, Edwards, CA.
THE F-18 SYSTEMS RESEARCH AIRCRAFT FACILITY
JOEL R. SITZ Dec. 1992 32 p Presented at the 1992 Aerotech Conference, Anaheim, CA, 5-8 Oct. 1992
(Contract RTOP 505-68-52)
(NASA-TM-4433; H-1844; NAS 1.15:4433) Avail: CASI HC A03/MF A01

To help ensure that new aerospace initiatives rapidly transition to competitive U.S. technologies, NASA Dryden Flight Research Facility has dedicated a systems research aircraft facility. The primary goal is to accelerate the transition of new aerospace technologies to commercial, military, and space vehicles. Key technologies include more-electric aircraft concepts, fly-by-light systems, flush airdata systems, and advanced computer architectures. Future aircraft that will benefit are the high-speed civil transport and the National AeroSpace Plane. This paper describes the systems research aircraft flight research vehicle and outlines near-term programs. Author

N93-17687# Army Research Inst. for the Behavioral and Social Sciences, Alexandria, VA.
SIMULATOR MOTION Final Report, Jun. 1990 - Dec. 1991
JOHN A. BOLDOVICI Sep. 1992 37 p
(Contract DA PROJ. 2Q2-63007-A-795)
(AD-A257683; ARI-TR-961) Avail: CASI HC A03/MF A01

This review analyzes the arguments for and against using various methods of force motion cuing in land-vehicle and aircraft simulators. Research literature was reviewed and opinions were solicited from 31 authorities, 24 of whom replied. Analysis of the literature and of the reasons given by the authorities for and against the use of force motion cuing indicated the following: (1) no transfer of training data support using motion-based rather than fixed-base simulators; (2) the absence of supporting data may be due to the unknown characteristics of motion used in transfer research, safety considerations that preclude conducting definitive transfer of training experiments, and deficiencies in experiments that lead to inadequate statistical power; and (3) objective examination of the effects of force motion cuing on transfer to land vehicles and aircraft requires developing and using reliable and safe tests for assessing the performance of tasks that cannot safely be performed in parent vehicles. In the absence of transfer data demonstrating the superiority of fixed-based or motion-based simulators, analyses to identify discriminative stimuli are recommended. The report presents algorithms for deciding for which tasks the use of force motion cuing in training is likely to facilitate transfer to parent vehicles and for deciding whether seat shakers, g-seats, or motion

bases are sufficient to provide discriminative stimuli for task performance. GRA

N93-17708# Army Cold Regions Research and Engineering Lab., Hanover, NH.
STATE-OF-THE-ART SURVEY OF FLEXIBLE PAVEMENT CRACK SEALING PROCEDURES IN THE UNITED STATES
ROBERT A. EATON and JANE ASHCRAFT Sep. 1992 25 p
(AD-A258050; CRREL-92-18) Avail: CASI HC A03/MF A01

A survey of all 50 United States was conducted in September of 1990 to determine the state of the art of crack sealing procedures on flexible asphalt concrete pavements. The results were tabulated and a summary report prepared. A meeting was held at the U.S. Army Cold Regions Research and Engineering Laboratory to discuss the draft report; the comments and suggestions received were incorporated into this report. At the meeting, the group identified the need for a trade organization to develop uniform specifications and terminology and to promote proper equipment, methodology, materials, training, and education in the pavement crack sealing industry. GRA

N93-17734# Naval Civil Engineering Lab., Port Hueneme, CA.
AN EXPERIMENTAL EXAMINATION OF THE THERMAL AND ACOUSTIC ENVIRONMENTS ON RUNWAY JOINT SEALS Final Report, Jun. 1988 - Sep. 1989
E. E. COOPER and C. DAHL Sep. 1992 107 p
(Contract NR PROJ. Y13-16)
(AD-A257965; NCEL-N-1846) Avail: CASI HC A06/MF A02

A test series was conducted at Edwards Air Force Base to determine noise and temperature environments that joint seal materials experience on an operational runway. Impingement of exhaust flow from jet engines creates an aerothermal environment for joint seal materials that contributes to, and accelerates, the deterioration and failure of joint seals. The aerothermal environment consists of noise (considered in this report as acoustically-induced as well as flow-induced fluctuations) and temperature. Current specifications for runway joint seal materials do not consider the effects of noise. The test data in this report show noise levels of 164 db at the joint seal surface. The conclusion is that the potential for energy transfer from exhaust flow noise is almost as high as the potential for energy transfer from exhaust flow temperature. GRA

N93-17793# Federal Aviation Administration, Washington, DC. Office of Airport Planning and Programming.
ESTIMATING THE REGIONAL ECONOMIC SIGNIFICANCE OF AIRPORTS
STEWART E. BUTLER and LAURENCE J. KIERNAN Sep. 1992 63 p
(AD-A257658; DOT/FAA/PP-92-6) Avail: CASI HC A04/MF A01

The United States has the world's most extensive airport system. The system is essential to national transportation, and there is a large Federal investment in it. However, most public airports are owned and operated by units of local government. Public airports must compete for funds with other governmental activities. They are scrutinized during budget preparation and may be the subject of public debate, particularly if major improvements or new construction are anticipated. They may even be the target of proposed restrictions aimed at limiting aircraft noise levels. In such instances, the future of an airport is determined primarily through the local political process. It is important that the public and their representatives appreciate the economic significance of airports if they are to continue to support them. This report is designed to assist analyses of the economic importance of airports. It is not intended for use in financial feasibility studies or cost/benefit analyses. Rather, it provides information that the average citizen may find useful when the current and future role of an airport is being discussed. One objective is to encourage a standard approach to the measurement of the economic significance of airports. GRA

N93-17875# National Aerospace Lab., Amsterdam (Netherlands). Flight Div.
FLIGHT SIMULATION EVALUATION OF THE FLYABILITY OF CURVED MLS APPROACHES WITH WIDE-BODY AIRCRAFT
L. J. J. ERKELENS and J. H. VANDRONKELAAR 30 Jun. 1990 123 p Sponsored by Royal Netherlands Air Force, and FAA
(NLR-TP-90238-U; ETN-93-93319) Avail: CASI HC A06/MF A02

A flight simulator study concerning the evaluation of flight director flown curved Microwave Landing System (MLS) approach paths with a simulated wide body transport aircraft is described. Four curved approach paths, consisting of two straight segments and one 90 deg circular segment with different straight final segments lengths, were investigated. Moreover an MLS equivalent of the 13R Canarsie visual approach at Kennedy airport New York (U.S.) was considered. Test objectives were: to demonstrate the flybility of curved approaches for wide body type of aircraft; to collect scientific data on pilot performance and operational acceptance for manually flown (flight director aided) curved approaches; to determine the operationally acceptable minimum straight final segment length. Test conditions included various wind and visual conditions. Winds yielding limiting conditions for category 2 operations and winds providing airframe limiting conditions, as far as magnitude of cross/tailwind comments are concerned, were included. Visibility and cloud base conditions ranged from category 2 to better than category 1 conditions. Test data were obtained as subjective and objective results. Subjective results concern pilot questionnaire responses and pilot comments, while the objective results concern among other things path tracking accuracy, including isoprobability contour plots and touchdown performance. ESA

N93-18520*# MCAT Inst., San Jose, CA.
STUDY OF OPTICAL TECHNIQUES FOR THE AMES UNITARY WIND TUNNEL, PART 7 Final Report
GEORGE LEE Jan. 1993 12 p
(Contract NCC2-716)
(NASA-CR-192165; NAS 1.26:192165; MCAT-93-02) Avail: CASI HC A03/MF A01

A summary of optical techniques for the Ames Unitary Plan wind tunnels are discussed. Six optical techniques were studied: Schlieren, light sheet and laser vapor screen, angle of attack, model deformation, infrared imagery, and digital image processing. The study includes surveys and reviews of wind tunnel optical techniques, some conceptual designs, and recommendations for use of optical methods in the Ames Unitary Plan wind tunnels. Particular emphasis was placed on searching for systems developed for wind tunnel use and on commercial systems which could be readily adapted for wind tunnels. This final report is to summarize the major results and recommendations. Author

N93-18766*# MCAT Inst., San Jose, CA.
STUDY OF OPTICAL TECHNIQUES FOR THE AMES UNITARY WIND TUNNEL: DIGITAL IMAGE PROCESSING, PART 6
GEORGE LEE Jan. 1993 38 p
(Contract NCC2-716)
(NASA-CR-192164; NAS 1.26:192164; MCAT-92-021) Avail: CASI HC A03/MF A01

A survey of digital image processing techniques and processing systems for aerodynamic images has been conducted. These images covered many types of flows and were generated by many types of flow diagnostics. These include laser vapor screens, infrared cameras, laser holographic interferometry, Schlieren, and luminescent paints. Some general digital image processing systems, imaging networks, optical sensors, and image computing chips were briefly reviewed. Possible digital imaging network systems for the Ames Unitary Wind Tunnel were explored. Author

N93-19280# National Aerospace Lab., Tokyo (Japan).
RAREFIED GAS NUMERICAL WIND TUNNEL. PART 7: OREX [KIHAKU KITAI SUUCHI FUUDOU. 7: OREX]
KATSUHISA KOURA and MIKINARI TAKAHIRA (Daiko Ltd., Japan) *In its* Proceedings of the Ninth NAL Symposium on Aircraft

Computational Aerodynamics p 37-40 Dec. 1991 In JAPANESE
Avail: CASI HC A01/MF A03

The 'Rarefied Gas Numerical Wind Tunnel (RGNWT)' constructed with the universal code described using the null-collision direct simulation Monte Carlo method is used for the simulation of rarefied gas flows around the Orbital Reentry EXperiment (OREX) vehicle. Some aerodynamic characteristics and flow field properties are presented. Author (NASDA)

N93-19288# National Aerospace Lab., Tokyo (Japan).
NUMERICAL WIND TUNNEL: REQUIREMENTS AND THE OUTLINE [SUUCHI FUUDOU: YOUKYUU YOUKEN TO GAIRYAKU]
HAJIME MIYOSHI *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 91-97 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

In this paper, it is shown that the Numerical Wind Tunnel (NWT) with an actual performance of more than 100 times higher than Fujitsu-VP400 is feasible using a multicomputer architecture and crossbar interconnection network. Author (NASDA)

N93-19289# National Aerospace Lab., Tokyo (Japan).
NUMERICAL WIND TUNNEL HARDWARE [SUUCHI FUUDOU NO HADOUEA]
HAJIME MIYOSHI, YOSHIRO YOSHIOKA (Fujitsu Ltd., Tokyo, Japan), MASAYUKI IKEDA (Fujitsu Ltd., Tokyo, Japan), and MORIYUKI TAKAMURA (Fujitsu Ltd., Tokyo, Japan) *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 99-106 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

In a few years, a computer which processes Computational Fluid Dynamics (CFD) programs over 100 times faster than the Fujitsu-VP400 and has a main memory capacity of more than 32 G bytes will be required for CFD technology to play an important role in aerospace research and development. A distributed main memory parallel processor is free from the memory throughput bottleneck which prevents the implementation of shared memory parallel processors with the necessary speed. In the light of regular characteristics of CFD codes, a distributed memory parallel processor is likely to deliver the above mentioned processing speed. Its characteristics include a physically distributed main memory which logically provides programmers with global and local memory views, processing elements with high speed Reduced Instruction Set Computer (RISC) scalar units and high speed vector units with large capacity vector registers, and a crossbar network which interconnects a large number of processing elements. Such a processor can be suitably called the 'Numerical Wind Tunnel'. This paper describes the basic main memory structure, system configuration, processing element, and interconnection network and communication mechanism of the Numerical Wind Tunnel. Author (NASDA)

N93-19290# National Aerospace Lab., Tokyo (Japan).
THE OPERATING SYSTEM FOR NUMERICAL WIND TUNNEL [SUUCHI FUUDOU NO OPERETEINGU SHISUTEMU]
MASAHIRO FUKUDA, KAZUYO SUEMATSU, MASAKO TUTIYA, AKIRA OZORA (Fujitsu Ltd., Tokyo, Japan), TAKASHI KUNAI (Fujitsu Ltd., Tokyo, Japan), and YOSHINORI SAKAMOTO (Fujitsu Ltd., Tokyo, Japan) *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 107-113 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

Numerical Wind Tunnel (NWT) is a Computational Fluid Dynamics (CFD) oriented parallel computer system with distributed memory. Conventional Operating System (OS) has been developed mainly based on computers with shared memory. Each processor of NWT has its own individual OS and each OS needs to work in collaboration with each other. Therefore OS itself has a characteristic of programs processed in parallel. In this paper, OS functions required for NWT is discussed with the parallelism of OS taken into account to attain effective managements of hardware resources and high speed processing of CFD programs. Author (NASDA)

N93-19291# National Aerospace Lab., Tokyo (Japan).
THE LANGUAGE PROCESSOR SYSTEM FOR THE NUMERICAL WIND TUNNEL [SUUCHI FUUDOU NO GENGO SHORI SOFUTOUEA]
MASAHIRO FUKUDA, TAKASHI NAKAMURA, MASAHIRO YOSHIDA, SHIN OKADA (Fujitsu Ltd., Tokyo, Japan), and SYUICHI NAKAMURA (Fujitsu Ltd., Tokyo, Japan) *In its* Proceedings of the Ninth NAL Symposium on Aircraft Computational Aerodynamics p 115-121 Dec. 1991 In JAPANESE
Avail: CASI HC A02/MF A03

The Numerical Wind Tunnel (NWT) is under research and development by NAL and Fujitsu joint activity. It is a parallel computer system of distributed memory architecture composed of vector processors, whose goal is to perform Computational Fluid Dynamics (CFD) simulation about 100 times faster than FACOM-VP400. In this paper three fundamental functions global data, parallel execution of DO-loop, and data decomposition and allocation, which the language processor system has to provide in order to realize parallel execution on the NWT are shown. FORTRAN77 is chosen as a basic programming language for NWT and some compiler directives is added to make effective use of the NWT. In this paper, the programming model of the NWT and the execution image with these directives are explained. Author (NASDA)

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ASTRONAUTICS

Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.

A93-18391
ASTRONAUTICS AND SOCIETY [KOSMONAVTIKA I OBSHCHESTVO]
V. S. AVDUEVSKII and L. V. LESKOV *In* Space industry: From experiments to industrial scales; Lectures Devoted to K.E. Tsiolkovsky's Ideas, 25th, Kaluga, Russia, Sept. 11-14, 1990, Transactions Moscow AN SSSR, Institut Istorii Estestvoznaniia i Tekhniki 1991 p. 3-14. In Russian. refs
Copyright

The economic, ecological, and social benefits of various space programs are assessed. It is noted that society can benefit from such programs as space manufacturing, manned space stations, solar electric power stations, an air-space transportation system, and lunar bases. Ways to finance such projects and avenues of space commercialization are examined. L.M.

A93-18717
DLR, ANNUAL REPORT 1991/92 [DLR, JAHRESBERICHT 1991/92]
Cologne Deutsche Forschungsanstalt fuer Luft- und Raumfahrt (ISSN 0938-2194) 1992 77 p. In German.
Copyright

DLR's annual report for 1991/92 is presented. The activities reviewed include: wind tunnel studies of aircraft flight prediction, outer space-related studies, radar remote sensing of the earth, Space Station studies, energy technology, solar energy experiments. C.D.

A93-19579* National Aeronautics and Space Administration, Washington, DC.

AIR-BREATHING HYPERSONIC CRUISE - PROSPECTS FOR MACH 4-7 WAVERIDER AIRCRAFT

ISAIAH M. BLANKSON (NASA, Hypersonics Research Div., Washington) Jun. 1992 17 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-437)

In the Mach 4-7 range, waverider aircraft are considered as candidates for both short- and long-range cruise missions, as hypersonic missiles, and as high L/D highly maneuverable craft. The potential for near- and far-term application of airbreathing engines to the waverider vehicle missions and concepts is presented. Attention is focused on the cruise mission and attempts are made to compare and contrast it with the accelerator mission. R.E.P.

A93-21108# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

DESIGN OF A HYPERSONIC WAVERIDER-DERIVED AIRPLANE

ROBERT J. PEGG, JAMES L. HUNT, DENNIS H. PETLEY (NASA, Langley Research Center, Hampton, VA), LEO BURKHARDT (NASA, Lewis Research Center, Cleveland, OH), DANIEL R. STEVENS, PAUL L. MOSES, S. Z. PINCKNEY, HANEE Z. KABIS, KEVIN A. SPOTH, WILLIAM M. DZIEDZIC (Lockheed Engineering and Sciences Co., Hampton, VA) et al. Jan. 1993 28 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0401) Copyright

The paper describes the first assessment study of a waverider-derived Mach 5 aircraft design using fuselage integrated-underslung over/under turboramjets with endothermic fuel. The study is based on a tanker-to-tanker mission, which begins at Mach 0.8 and 30,000 feet, with the vehicle accelerating to Mach 12 at constant altitude and then to Mach 5 while climbing to about 90,000 feet. The paper describes the vehicle, the aerodynamic analysis, and the propulsion system and its installed performance, structure design, and analysis. The mission simulation was run using the CSOTAV code developed by the NASA Langley Research Center. I.S.

A93-21148* National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

RESULTS FROM A GPS SHUTTLE TRAINING AIRCRAFT FLIGHT TEST

PENNY E. SAUNDERS, MOISES N. MONTEZ (NASA, Johnson Space Center, Houston, TX), MICHAEL C. ROBEL, DAVID N. FEUERSTEIN, MIKE E. AERNI (Lockheed Engineering and Sciences Co., Houston, TX), S. SANGCHAT, LON M. RATER, SCOTT P. CRYAN, LYDIA R. SALAZAR (McDonnell Douglas Space Systems Co., Houston, TX), MARK P. LEACH (Texas Univ., Austin) et al. *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 423-432. refs

A series of Global Positioning System (GPS) flight tests were performed on a National Aeronautics and Space Administration's (NASA's) Shuttle Training Aircraft (STA). The objective of the tests was to evaluate the performance of GPS-based navigation during simulated Shuttle approach and landings for possible replacement of the current Shuttle landing navigation aid, the Microwave Scanning Beam Landing System (MSBLS). In particular, varying levels of sensor data integration would be evaluated to determine the minimum amount of integration required to meet the navigation accuracy requirements for a Shuttle landing. Four flight tests consisting of 8 to 9 simulation runs per flight test were performed at White Sands Space Harbor in April 1991. Three different GPS receivers were tested. The STA inertial navigation, tactical air navigation, and MSBLS sensor data were also recorded during each run. C-band radar aided laser trackers were utilized to provide the STA 'truth' trajectory. Author

A93-21160

COMPLEMENTARY MLS AND GNSS OPERATIONS

ALEXANDER E. SMITH (Booz, Allen & Hamilton, Inc., Arlington, VA), KAREN L. BURCHAM (FAA, Washington), and KEITH D. MCDONALD (Sat Tech Systems, Inc., Arlington, VA) *In* ION GPS-91; Proceedings of the 4th International Technical Meeting of the Satellite Division of the Institute of Navigation, Albuquerque, NM, Sept. 11-13, 1991 Washington Institute of Navigation 1991 p. 863-871. refs

A framework for developing complementary roles for the MLS and the Global Navigation Satellite System (GNSS) is established. Emphasis is given to the development by the FAA and the aviation industry of techniques and the infrastructure to support fully integrated MLS and GNSS operations. The operational role of each system is evaluated during each flight phase, and the benefits attributable to reduced delays and optimum routings are discussed. C.D.

A93-21765

SIR TECHNOLOGY HELPS ENSURE SAFE LANDINGS FOR NASA

GARY KRATOCHVIL, THOMAS FENNER (Geophysical Survey Systems, Inc., North Salem, NH), and RICHARD BENSON (Technos, Inc., Miami, FL) Materials Evaluation (ISSN 0025-5327) vol. 50, no. 12 Dec. 1992 p. 1412, 1414.
Copyright

The use of a subsurface interface radar (SIR) system to ensure that lake-bed runways are free of unseen fissures and voids is described. SIR systems nonintrusively detect anomalies underground or embedded in concrete and other man-made materials. The effectiveness of an SIR system is influenced by the type of soil, with best results obtained for dry, sandy soil. Results of the application of SIR technology to Edwards AFB runways are summarized. V.L.

A93-21908

CANADIAN LOW-GRAVITY RESEARCH USING PARABOLIC AIRCRAFT

GLEN S. CAMPBELL, L. VEZINA (Canadian Space Agency, Ottawa, Canada), and J. F. AITKEN (National Research Council of Canada, Ottawa) Microgravity Science and Technology (ISSN 0938-0108) vol. 5, no. 3 Dec. 1992 p. 160-165. refs
Copyright

An active experimental program being implemented by Canada in microgravity, which relies heavily on the use of parabolic aircraft, is discussed. The advantages of zero-gravity aircraft include low cost and quick turnaround. These aircraft have demonstrated their value for prototyping experimental hardware developments planned for flight at other facilities, such as sounding rockets and Shuttle-based carriers which are supported by the Canadian Space Agency. C.A.B.

A93-22282#

OVERVIEW OF JAPANESE AEROSPACE PLANE

TATSUO YAMANAKA (National Aerospace Lab., Chofu, Japan) Dec. 1992 12 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5005) Copyright

The Japanese NAL, NASDA, and ISAS agencies have undertaken development of a Highly Maneuverable Experimental Spaceplane ('HIMES') which will integrate hypersonic technologies currently under development. A development status evaluation of these activities is presented. Attention is given to the configurational features of HIMES, its aerodynamic developmental tests to date, structures and materials considerations, flight control/guidance systems, airbreathing propulsion options, and CFD modeling. O.C.

A93-22287*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

EVALUATION OF SOME SIGNIFICANT ISSUES AFFECTING TRAJECTORY AND CONTROL MANAGEMENT FOR AIR-BREATHING HYPERSONIC VEHICLES

PHILIP D. HATTIS and HARVEY L. MALCHOW (Charles Stark Draper Lab., Inc., Cambridge, MA) Dec. 1992 10 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(Contract NAS1-18565)
(AIAA PAPER 92-5011) Copyright

Horizontal takeoff airbreathing-propulsion launch vehicles require near-optimal guidance and control which takes into account performance sensitivities to atmospheric characteristics while satisfying physically-derived operational constraints. A generic trajectory/control analysis tool that deepens insight into these considerations has been applied to two versions of a winged-cone vehicle model. Information that is critical to the design and trajectory of these vehicles is derived, and several unusual characteristics of the airbreathing propulsion model are shown to have potentially substantial effects on vehicle dynamics. O.C.

A93-22288*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CLOSED FORM SOLUTIONS OF CONSTRAINED TRAJECTORIES - APPLICATION IN OPTIMAL ASCENT OF AEROSPACE PLANE
PING LU and JOHN SAMSUNDAR (Iowa State Univ. of Science and Technology, Ames) Dec. 1992 6 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(Contract NAG1-1255)
(AIAA PAPER 92-5012) Copyright

The present consideration of the flight trajectory of hypersonic aerospace vehicles subject to a class of path constraints notes the constrained dynamics to constitute a natural two-timescale system, so that problems of trajectory optimization and guidance can be dramatically simplified by means of the asymptotic analytical solutions thus obtained. An illustrative application in ascent trajectory optimization for an aerospace vehicle is presented. O.C.

A93-22289#
ROBUST CONTROL OF THE SEPARATION OF HYPERSONIC LIFTING VEHICLES
GOTTFRIED SACHS and WOLFGANG SCHODER (Muenchen, Technische Univ., Munich, Germany) Dec. 1992 9 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5013) Copyright

A control technique which achieves maximum safety as well as optimum performance is entailed by the problem posed by the separation of two-stage lifting vehicles at hypersonic speeds. The present solutions for such a separation maneuver emphasize control robustness, in view to the large force and moment changes anticipated for the separating vehicles. Robust control will also be able to deal with systems having large parameter uncertainties. Maneuver optimization results are presented which emphasize flight safety considerations. O.C.

A93-22315*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ARC JET TESTING IN NASA AMES RESEARCH CENTER THERMOPHYSICS FACILITIES
ALIZA BALTER-PETERSON, FRANK NICHOLS, BRIAN MIFSUD (Eloret Inst., Sunnyvale, CA), and WENDELL LOVE (NASA, Ames Research Center, Moffett Field, CA) Dec. 1992 13 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992
(AIAA PAPER 92-5041) Copyright

The Arc Jet Complex facilities at NASA Ames and their performance capabilities and support systems are presented. An overview of the typical testing procedures is provided. Attention is focused on a basic understanding of the types of facilities available at Ames for aerothermodynamic testing. R.E.P.

A93-22324#
ATMOSPHERIC REENTRY FLIGHT TEST OF WINGED SPACE VEHICLE
YOSHIFUMI INATANI, RYOJIRO AKIBA, MOTOKI HINADA, and MAKOTO NAGATOMO (Inst. of Space and Astronautical Science, Sagamihara, Japan) Dec. 1992 9 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5053) Copyright

A review of the atmospheric reentry flight experiment of a winged space vehicle is presented. This is the first Japanese atmospheric reentry flight of the control lifting vehicle. Details of the test and a summary of the current status of the post flight analysis are described. R.E.P.

A93-22328*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AERO-SPACE PLANE FIGURES OF MERIT
JAMES L. HUNT (NASA, Langley Research Center, Hampton, VA) and JOHN G. MARTIN (Lockheed Engineering and Sciences Co., Hampton, VA) Dec. 1992 10 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5058) Copyright

The design environment of the aerospace plane is variable rich, intricately networked and sensitivity intensive. To achieve a viable design necessitates addressing three principal elements: knowledge of the 'figures of merit' and their relationships, the synthesis procedure, and the synergistic integration of advanced technologies across the discipline spectrum. This paper focuses on the 'figures of merit' that create the design of an aerospace plane. R.E.P.

A93-22870
A DYNAMIC INVERSION CONTROL APPROACH FOR HIGH-MACH TRAJECTORY TRACKING
BLAISE MORTON (Honeywell Systems and Research Center, Minneapolis, MN) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1332-1336. refs
Copyright

The author describes some work related to the NASP program that was performed several years ago. The original motivation was to understand how atmospheric variations and dynamic uncertainties can affect trajectories of the NASP vehicle during atmospheric ascent. In an earlier publication (1989) the author presented an analytic technique used in conjunction with the algorithms described here to perform perturbed trajectory analyses. The approximate models and the tracking and control strategies used to generate the ascent trajectories are discussed. I.E.

A93-23042#
AN ESTIMATE OF THE 'DOOMED PROPELLANT FRACTION' FOR A SUPERDETONATIVE RAM ACCELERATOR
K. GHORBANIAN and D. T. PRATT (Washington Univ., Seattle) Jan. 1993 15 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0359) Copyright

Guidelines enabling prediction of size and performance limits of a 'Superdetonative Ram Accelerator' are presented. Relations providing the fraction of propellant gases which will necessarily be consumed on the projectile forebody prior to being ingested into the annulus, utilizing engineering correlations for reacting detached bow shock shapes over sphere-cones, are established. Results indicate strong dependency of the SDRA performance limits on the propellant composition, the projectile cone half-angle, and the nose radius required for thermal protection. Author

A93-23058#
NUCLEAR THERMAL ROCKET ENTRY HEATING AND THERMAL RESPONSE PRELIMINARY ANALYSIS
DONALD L. POTTER, LEONARD W. CONNELL, C. C. WONG, and MARC W. KNISKERN (Sandia National Labs., Albuquerque,

NM) Jan. 1993 7 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 93-0378)

This preliminary study analyzes the atmospheric entry of a solid core nuclear thermal rocket (NTR) engine under three accidental entry scenarios. Depending on the scenario, results of the analysis showed, without external thermal protection, an aluminum pressure vessel will fail at altitudes ranging from 25 to 73 km. Subsequent release of the core materials occurs. The graphitic based core materials will undergo partial ablation, with the percent mass loss depending on the geometry of the fuel elements. A carbon-phenolic thermal protection system was sized to prevent pressure vessel aerothermal failure. It was found to increase the mass of the NTR by approximately 15 percent. Author

A93-23059#
OVERVIEW OF TECHNICAL CHALLENGES OF REENTRY ANALYSIS OF RADIOISOTOPE HEAT SOURCES
E. F. LUCERO (Johns Hopkins Univ., Laurel, MD) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by DOE refs
(AIAA PAPER 93-0379) Copyright

The analytical and experimental effort conducted by the Applied Physics Laboratory of the Johns Hopkins University for the U.S. Department of Energy in predicting the reentry ablation and thermostructural response of heat sources is described. The environment addressed is that posed by accidental entries of heat sources from an Earth Gravity Assist trajectory, such as that of the Galileo mission. Also described are the analytical tools and limitations of the analytical methods used for thermal and thermostructural analysis and of the experimental data bases used for material thermal and mechanical properties in the analyses for these environments. These limitations are translated into challenges for improving reentry predictions and for testing of materials at very high temperatures and for ablation tests at very high heating rates and pressures. Author

A93-23256*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ANALYSIS OF A HYPERSONIC WAVERIDER RESEARCH VEHICLE WITH A HYDROCARBON SCRAMJET ENGINE
GREGORY A. MOLVIK, JEFFREY V. BOWLES, and LOC C. HUYNH (NASA, Ames Research Center, Moffett Field, CA) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NCC2-498; NCC2-746)
(AIAA PAPER 93-0509) Copyright

The results of a feasibility study of a hypersonic waverider research vehicle with a hydrocarbon scramjet engine are presented. The integrated waverider/scramjet geometry is first optimized with a vehicle synthesis code to produce a maximum product of the lift-to-drag ratio and the cycle specific impulse, hence cruise range. Computational fluid dynamics (CFD) is then employed to provide a nose-to-tail analysis of the system at the on-design conditions. Some differences are noted between the results of the two analysis techniques. A comparison of experimental, engineering analysis and CFD results on a waverider forebody are also included for validation. Author

A93-23258#
THE EFFECTS OF HYPERSONIC FLIGHT TEST REQUIREMENTS ON RESEARCH VEHICLE DESIGN
A. C. GRANTZ, R. T. CERVISI, J. W. HANEY, K. S. PATEL, and H. L. RISHEL (Rockwell International Corp., Downey, CA) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0511) Copyright

This paper compares and studies several launch, acceleration, and cruise concepts that have satisfied a variety of hypersonic research goals. The aerodynamic characteristics, propulsion performance, and propellant fractions of waverider derived vehicles are employed to estimate relative weight, size, and cost of differing approaches to meeting the research objectives. For the Mach 14 examples studied, a small boosted vehicle had about the same operational costs as a larger airbreathing hydrogen vehicle. R.E.P.

A93-23345#
CONSTRUCTION OF A ONE-THIRD SCALE MODEL OF THE NASP
K. R. HALL, S. W. BROWN, A. G. BENNETT, and M. RAIS-ROHANI (Mississippi State Univ., Mississippi State) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0427) Copyright

An overview is presented of the development by the students of Mississippi State University and the facilities at Raspet Flight Research Laboratory for the construction of a one-third scale model of the National Aerospace Plane. The entire construction process is described focusing upon the use of a five-axes gantry robot router for building the molds for making composite components. A pictorial history of the model construction is provided. R.E.P.

N93-16629*# Virginia Univ., Charlottesville. School of Engineering and Applied Science.
TECHNICAL NEEDS AND RESEARCH OPPORTUNITIES PROVIDED BY PROJECTED AERONAUTICAL AND SPACE SYSTEMS Final Report, 1 Aug. 1990 - 31 May 1991
AHMED K. NOOR Apr. 1992 24 p
(Contract NAGW-2266)
(NASA-CR-192124; NAS 1.26:192124; UVA/528366/CE92/101)
Avail: CASI HC A03/MF A01

The overall goal of the present task is to identify the enabling and supporting technologies for projected aeronautical and space systems. A detailed examination was made of the technical needs in the structures, dynamics and materials areas required for the realization of these systems. Also, the level of integration required with other disciplines was identified. The aeronautical systems considered cover the broad spectrum of rotorcraft; subsonic, supersonic and hypersonic aircraft; extremely high-altitude aircraft; and transatmospheric vehicles. The space systems considered include space transportation systems; spacecrafts for near-earth observation; spacecrafts for planetary and solar exploration; and large space systems. A monograph is being compiled which summarizes the results of this study. The different chapters of the monograph are being written by leading experts from governmental laboratories, industry and universities. Author

N93-18085*# Eloret Corp., Sunnyvale, CA.
EXPERIMENTAL INVESTIGATION OF NOZZLE/PLUME AERODYNAMICS AT HYPERSONIC SPEEDS Progress Report, 1 Feb. - 30 Nov. 1992
K. HEINEMANN, DAVID W. BOGDANOFF, and JEAN-LUC CAMBIER (Eloret Corp., Sunnyvale, CA.) 3 Dec. 1992 150 p
(Contract NCC2-487)
(NASA-CR-191368; NAS 1.26:191368) Avail: CASI HC A07/MF A02

The work performed by D. W. Bogdanoff and J.-L. Cambier during the period of 1 Feb. - 31 Oct. 1992 is presented. The following topics are discussed: (1) improvement in the operation of the facility; (2) the wedge model; (3) calibration of the new test section; (4) combustor model; (5) hydrogen fuel system for combustor model; (6) three inch calibration/development tunnel; (7) shock tunnel unsteady flow; (8) pulse detonation wave engine; (9) DCAF flow simulation; (10) high temperature shock layer simulation; and (11) the one dimensional Godunov CFD code.

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CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

A93-18636

ELASTIC CONSTANTS FOR UNIDIRECTIONAL BORON-EPOXY COMPOSITES

C. M. SCALA and P. A. DOYLE (Defence Science and Technology Organisation, Aeronautical Research Lab., Port Melbourne, Australia) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11A; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 585-592. refs

Copyright

A scheme is presented for the determination of seven out of the nine elastic constants of an orthotropic composite's overlays, which are required for calculation of the properties of interface waves between that overlay and a substrate. A laser line-source of ultrasound was used to overcome the one-sidedness of access and the single orientation of a composite overlay. Elastic constants are determined for a unidirectional boron-epoxy plate; these constants are used to establish the presence (or absence) of interface waves, as well as to determine interface wave speeds, for a boron-epoxy plate that is well bonded to various metallic substrates. O.C.

A93-19330

EFFECTS OF BACK-PRESSURE IN A LEAN BLOWOUT RESEARCH COMBUSTOR

G. J. STURGESS (Pratt & Whitney Group, East Hartford, CT), S. P. HENEGHAN, M. D. VANGSNESS, D. R. BALLAL (Dayton Univ., OH), A. L. LESMERISES, and D. SHOUSE (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1992 15 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs

(Contract F33615-87-C-2767; F33615-87-C-2822)

(ASME PAPER 92-GT-81)

Experimental information is presented on the effects of back-pressure on flame-holding in a gaseous fuel research combustor. Data for wall temperatures and static pressures are used to infer behavior of the major recirculation zones, as a supplement to some velocity and temperature profile measurements using LDV and CARS systems. Observations of flame behavior are also included. Lean blowout is improved by exit blockage, with strongest sensitivity at high combustor loadings. It is concluded that exit blockage exerts its influence through effects on the jet and recirculation zone shear layers. Author

A93-19341

MARKOV FATIGUE IN SINGLE CRYSTAL AIRFOILS

CHARLES ANNIS and DANIEL P. DE LUCA (Pratt & Whitney Group, West Palm Beach, FL) Jun. 1992 5 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs

(ASME PAPER 92-GT-95)

The influence of microstructure on macrobehavior in single crystal airfoils is considered by treating the micromechanics of damage accumulation as a Markov process. Single crystal materials are described, and the ways in which they differ from more conventional (isotropic) alloys are examined. Relationships among the more probable of several competing microstructural damage mechanisms and specific rate-controlling parameters are suggested. The states of microstructural damage are described and cataloged, and the various avenues of damage accumulation are investigated. The Markov paradigm is reviewed as it applies to these materials. A Markov model is presented to describe the complex behavior observed in single crystals, and its use in lifting gas turbine engine airfoils is discussed. C.A.B.

A93-19354

EXPERIMENTAL AND COMPUTATIONAL INVESTIGATION OF FLOW IN CATALYTIC MONOLITH CHANNELS

G. C. WILSON, M. F. BARDON (Royal Military College of Canada, Kingston), and J. J. WITTON (Cranfield Inst. of Technology, United Kingdom) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Rolls-Royce Industrial and Marine Gas Turbines, Ltd. and DND refs

(ASME PAPER 92-GT-118)

Monolith optimization is necessary for maximum efficiency during catalytic combustion. This paper describes a study undertaken to investigate the flow in catalytic monolith channels. A super-scale model of a single passage in a ceramic catalyst monolith was constructed and studied using pure air as the working fluid. Combustion of a representative natural gas mixture at the catalyst surface was simulated by electrical heating of the channel walls. The flow-field was probed with hot wire anemometers and fine wire thermocouples to obtain velocity and temperature data. Concurrently, the PHOENICS CFD package was used to model the flow. Results confirmed the presence of secondary flows and illustrated the effects of channel shape. The results are discussed as to their relevance to the design of a monolithic combustor for gas turbine applications. Author

A93-19356

APPLICATION OF A SULPHUR-DOPED ALKANE SYSTEM TO THE STUDY OF THERMAL OXIDATION OF JET FUELS

E. G. JONES and W. J. BALSTER (Systems Research Labs., Inc., Dayton, OH) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs

(Contract F33615-90-C-2033)

(ASME PAPER 92-GT-122)

A system of diphenyldisulphide in hexadecane was selected for modeling the formation of insolubles in jet fuels. The system was stressed in a series of flask tests at 185 C under fixed oxygen flow. The quantity of filterable insoluble solids and insoluble gums was measured as a function of time and found to increase linearly following an initial induction period. Rates associated with the linear growth were evaluated for a series of oxygen flows to obtain the oxygen dependence of insoluble-solid and insoluble-gum formation. Results indicate that insoluble gums and insoluble solids are formed by independent processes. Bulk and surface rates show a linear correlation, indicating that the precursors to insolubles formed in the bulk and those formed on the surface are similar. Author

A93-19366

COHERENT ANTI-STOKES RAMAN SCATTERING (CARS) THERMOMETRY IN A MODEL GAS TURBINE CAN COMBUSTOR

J. Y. ZHU, T. TSURUDA, W. A. SOWA, and G. S. SAMUELSEN (California Univ., Irvine) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by General Motors Co. refs

(Contract F08635-90-G-0100)

(ASME PAPER 92-GT-134)

Non-intrusive, spatially resolved instantaneous temperature measurements are presented that were obtained from a reacting spray flame in a model gas turbine can combustor using coherent anti-Stokes Raman scattering (CARS) thermometry. The results show that CARS measurements agree with thermocouple measurements at the exit of the combustor. The liquid droplet induced dielectric breakdown is not an obstacle in applying CARS to reacting sprays. The CARS measured temperature field also indicates that there is a relatively cool region (T less than 1000 K) near the nozzle tip. Reaction occurs in the region where large numbers of droplets are present and in the interface of the

swirl-induced recirculation zone. This study demonstrates that CARS is a viable diagnostic tool for non-intrusive, instantaneous temperature measurements in practical spray flames. Author

A93-19367
THE COMBUSTION OF DROPLETS WITHIN GAS TURBINE COMBUSTORS - SOME RECENT OBSERVATIONS ON COMBUSTOR EFFICIENCY
J. ODGERS, D. KRETSCHMER (Univ. Laval, Quebec, Canada), and G. F. PEARCE (Defence Science and Technology Organisation, Aeronautical Research Lab., Melbourne, Australia) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-135)
The process of droplet combustion in gas turbine combustors is presently investigated for the cases of three different simplex atomizers at each of the operating conditions for three fuels. The measured combustion efficiencies indicate no effects due to droplet size; it is suggested that these effects are reflected in a 'transfer number', and related to diffusional rather than evaporative phenomena. A comprehensive review of experimental data is undertaken. O.C.

A93-19372
EVALUATION OF SIMPLE ALUMINIDE AND PLATINUM MODIFIED ALUMINIDE COATINGS ON HIGH PRESSURE TURBINE BLADES AFTER FACTORY ENGINE TESTING - ROUND II
JEFFREY A. CONNOR (GE Aircraft Engines, Cincinnati, OH) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-140)
This paper presents results of factory engine testing of simple aluminide and platinum modified aluminide coatings. Simple aluminide coatings were produced using pack cementation processes. Platinum modified aluminide coatings were produced using three aluminiding processes; pack cementation, above-the-pack or out-of-contact processing, and chemical vapor deposition. These coatings were evaluated on both directionally solidified and single crystal nickel base superalloy turbine blades. These high pressure turbine blades were tested in a commercial high bypass turbofan engine operating predominantly in a high temperature oxidation environment. Included in this paper are discussions of coatings phase stability, coating growth due to diffusion during engine operation, comparison of coating performance and assessment of remaining coating life after engine testing. Author

A93-19374
CORROSION RESISTANCE OF INCONEL ALLOY 617 IN SIMULATED GAS TURBINE ENVIRONMENTS
P. GANESAN, G. D. SMITH, and D. H. YATES (Inco Alloys International, Inc., Huntington, WV) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-142)
The Inconel Alloy 617, a solid solution-strengthened Ni-Cr-Mo alloy with 1.2 percent Al, furnishes exceptional high-temperature strength and oxidation/carburizaton resistance. Attention is presently given to the behavior of this alloy in isothermal and cyclic oxidation, carburization, and burner rig oxidation/sulfidation environments. Mechanical properties data presented indicate the stability of the alloy upon extended exposure to high temperatures, relative to the properties of INCO-HX and Haynes 188 and 230 in similar conditions. O.C.

A93-19427
THE EVOLUTION OF THERMAL BARRIER COATINGS IN GAS TURBINE ENGINE APPLICATIONS
SUSAN M. MEIER and DINESH K. GUPTA (Pratt & Whitney Group, East Hartford, CT) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-203)
The thermal insulation benefit provided by plasma deposited thermal barrier coatings (TBC) lengthens the durability of combustors in gas turbine engines. Enhancements to the underlying metallic bond coat, the ceramic microstructure, and the ceramic composition have lead to the utilization of TBCs in the turbine section of the engine. The latest optimization of the composition and processing for increased durability electron beam-physical vapor deposited zirconia permits TBCs to be successfully employed in the most demanding rotating and stationary parts. R.E.P.

A93-19532
EROSION CHARACTERISTICS OF CERAMIC PARTICULATE AND WHISKER REINFORCED ALUMINUM COMPOSITES
SURESH GUPTA (Rolls-Royce, Inc., Atlanta, GA) Jun. 1992 4 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992
(ASME PAPER 92-GT-369)
A potentially serious problem anticipated in using silicon carbide particulate/whisker reinforced aluminum in the cold sections of front end engine components has been the behavior of the composite in particulate erosion. This paper describes a test program undertaken to study this problem and discusses the results. It was found that the erosion rate of such composites can be considerably higher, and the characteristic erosion behavior significantly different, than that of nonreinforced aluminum alloys. New mechanisms of material removal that occur are discussed. C.D.

A93-19547* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CERAMIC MATRIX COMPOSITES FOR ROCKET ENGINE TURBINE APPLICATIONS
THOMAS P. HERBELL and ANDREW J. ECKEL (NASA, Lewis Research Center, Cleveland, OH) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-394)
A program to establish the potential for introducing fiber reinforced ceramic matrix composites (FRCMC) in future rocket engine turbopumps was instituted in 1987. A brief summary of the overall program (both contract and in-house research) is presented. Tests at NASA Lewis include thermal upshocks in a hydrogen/oxygen test rig capable of generating heating rates up to 2500 C/sec. Post thermal upshock exposure evaluation includes the measurement of residual strength and failure analysis. Test results for monolithic ceramics and several FRCMC are presented. Hydrogen compatibility was assessed by isothermal exposure of monolithic ceramics in high temperature gaseous hydrogen plus water vapor. Author

A93-19565
EROSION RESISTANT TITANIUM NITRIDE COATING FOR TURBINE COMPRESSOR APPLICATIONS
J. LIBURDI, D. R. NAGY (Liburdi Engineering, Ltd., Hamilton, Canada), and V. R. PARAMESWARAN (National Research Council of Canada, Ottawa) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by National Research Council of Canada and DND refs
(ASME PAPER 92-GT-417)
The development and application of a thin ceramic titanium nitride coating to enhance the erosion resistance of compressor airfoils are presented. The coatings were formed by a reactive ion coating process and optimized to produce a very adherent erosion resistant coating structure. It is shown that titanium nitride coatings are suitable for operations and can be retrofitted on existing engines to enhance the service life of the compressors. R.E.P.

A93-19581
CERAMICS FOR AERO-ENGINE APPLICATIONS

J. WORTMANN (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Germany) and K. M. PREWO (United Technologies Research Center, East Hartford, CT) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-439)

A critical requirement exists for the development of ceramic gas turbine engine components that are safe and reliable. Elements of this design methodology are mechanical models of fracture processes and growth rates, together with statistical models of microstructures and flaw populations. Fiber-reinforced ceramics have shown that they can exhibit the type of failure models and crack growth resistance typical of polymer-matrix composites; these ceramic-matrix composites have been fabricated into large complex static and rotating components, and are undergoing durability testing. O.C.

A93-20129#
SEEDING MATERIALS FOR USE IN LASER ANEMOMETRY
KELLY R. SABROSKE (USAF, Aero Propulsion and Power Directorate, Wright-Patterson AFB, OH) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0006)

A study was conducted to find a seed particle suitable for laser anemometry in the Compressor Research Facility, Wright-Patterson Air Force Base, Ohio. Prospective seeding materials were evaluated and tested to ensure that both the laser anemometer and the CRF requirements were met. A Laser Transit Anemometer was used to measure the velocity lag that particles experience in response to an oblique shock wave. The oblique shock wave was created by a wedge with a 10 degree turning angle in a Mach 2.0 flow. Specifically, the velocity lags of 0.8 micron diameter polystyrene latex (PSL) and 0.9 micron diameter glycerin particles were measured to be 4 mm and 6 mm, respectively. The PSL followed the flow with 33 percent more accuracy than did the glycerin. Further development of the glycerin seed injection system will be investigated in the future with the goal of minimizing the velocity lag of glycerin. Author

A93-20155*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PLANAR IMAGING OF OH DENSITY DISTRIBUTIONS IN A SUPERSONIC COMBUSTION TUNNEL
T. M. QUAGLIAROLI, G. LAUFER, R. H. KRAUSS, and J. C. MCDANIEL, JR. (Virginia Univ., Charlottesville) Jan. 1993 7 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG1-795)
(AIAA PAPER 93-0042) Copyright

Images of absolute OH number density were obtained using planar laser-induced fluorescence (PLIF) in a supersonic H2-air combustion tunnel. A tunable KrF excimer laser was used to excite the Q2(11) ro-vibronic line. Calibration of the PLIF images was obtained by referencing the signal measured in the flame to that obtained by the excitation of OH produced by thermal dissociation of H2O in an atmospheric furnace. Measurement errors due to uncertainty in internal furnace atmospheric conditions and image temperature correction are estimated. Author

A93-21651
STATIC TESTS OF JET FUEL THERMAL AND OXIDATIVE STABILITY
SHAWN P. HENEGHAN (Dayton, Univ., OH), STACY L. LOCKLEAR, DAVID L. I. GEIGER, STEVEN D. ANDERSON (USAF, Wright Lab., Wright-Patterson AFB, OH), and WILLIAM D. SCHULZ (Eastern Kentucky Univ., Richmond, KY) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 5-9. refs
(Contract F33615-87-C-2767)
Copyright

Jet fuels and jet fuel surrogate have been thermally stressed to simulate the time/temperature history of aircraft fuel handling systems. Surrogate fuels were used to develop quantitative measurement techniques to assess fuel stability in static tests and compare the results with flowing tests. A variety of experimental techniques including Fourier transform infrared (IR), gas chromatography with atom-sensitive atomic-emission detection and high-pressure liquid chromatography have been used to study stressed and unstressed fuels. Quantitative and qualitative measurements of the deposits and the fuels are presented. In general, the static tests described here indicate that there is good agreement between static and flowing tests concerning the quality of a fuel. However to adequately assess fuel stability, the availability of oxygen must be limited. Arbitrarily increasing the oxygen availability is likely to yield results which are not applicable to oxygen-starved stressing processes. Furthermore, contrary to expectations, the rate at which a fuel oxidizes is shown to be inversely related to the rate of formation of insoluble products. Author

A93-21666
NUMERICAL ANALYSIS OF REACTING FLOW USING FINITE RATE CHEMISTRY MODELS
CHAE M. RHIE (Pratt & Whitney Group, East Hartford, CT), STEVEN T. STOWERS, and HOUSHANG B. EBRAHIMI (Pratt & Whitney Group, West Palm Beach, FL) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 119-126. Previously cited in issue 09, p. 1314, Accession no. A89-25375 refs
Copyright

A93-21678
POTENTIAL AEROSPACE APPLICATIONS FOR METAL MATRIX COMPOSITES
D. CHARLES (British Aerospace /Commercial Aircraft/, Ltd., Bristol, United Kingdom) Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering (ISSN 0954-4100) vol. 206, no. G2 1992 p. 105-110. refs
Copyright

A development status evaluation is presented for current and prospective applications of Al- and Ti-alloy matrix composites. While many prototype applications have exhibited weight savings of the order of up to 60 percent for strength comparable to that of conventional structures, high basic materials costs have precluded implementation on an industrial scale; SiC fibers typically cost $5000/kg. The cost penalty for discontinuously reinforced Al alloys is considerably lower, with about $100/km being typical for P/M-procuced MMCs; but these systems have commensurately less impressive structural efficiency improvements. O.C.

A93-21699
EFFECTS OF GRAIN SIZE AND CARBIDES ON THE CREEP RESISTANCE AND RUPTURE PROPERTIES OF A CONVENTIONALLY CAST NICKEL-BASE SUPERALLOY
AHMET BALDAN (Council for Scientific and Industrial Research, Div. of Materials Science and Technology, Pretoria, South Africa) Zeitschrift fuer Metallkunde (ISSN 0044-3093) vol. 83, no. 10 Oct. 1992 p. 750-757. refs
Copyright

The effects of grain size and carbides on the creep resistance and rupture properties of the conventionally cast IN-100 superalloy have been investigated in some detail. It is observed that the optimum values of creep strength and rupture properties, as creep life and strain, are obtained at a specific grain size. This optimum grain size for the present alloy is close to 545 microns. At this critical grain size the carbide particle density is the highest, whereas above and below this critical grain size the carbide density decreases. Author

A93-21731
COMBUSTION PERFORMANCE OF A HYDROGEN-FUELED SMALL COMBUSTOR FOR A MICRO GAS TURBINE
SABURO YUASA and NOBORU GOTO Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol.

58, no. 551 July 1992 p. 2288-2295. In Japanese. refs
Copyright

A hydrogen-burning small test combustor without air holes in a linear wall was designed on the basis of a concept as for lean combustion of hydrogen in a primary combustion zone under conditions of very strong swirl. After some preliminary work on the test combustor, a hydrogen-burning complete combustor for use in a hydrogen-fueled micro gas turbine was developed. The combustion test of the complete combustor showed that it was capable of maintaining very stable and efficient combustion over the required range of engine speeds and operation conditions. The combustor had the high rate of volumetric heat release of 3.5 x 10 exp 3 MW/(cu m MPa), and attained high combustion efficiencies of over 99.95 percent. Hydrogen combustion in the combustor could result in low NO(x) emission levels in comparison with hydrocarbon combustors. Author

A93-21999
A STUDY OF THE FLEXURAL PROPERTIES OF CARBON-EPOXY COMPOSITES IN CERTAIN ENVIRONMENTS
C. C. LEE (New South Wales Univ., Kensington, Australia), G. FREISCHMIDT, R. S. P. COUTTS (CSIRO, Div. of Forest Products, Clayton, Australia), A. G. CROSKY, and S. BANDYOPADHYAY (New South Wales, Univ., Kensington, Australia) Journal of Materials Science Letters (ISSN 0261-8028) vol. 11, no. 23 Dec. 1, 1992 p. 1599-1601. refs
Copyright

A study is conducted of the effects of room-temperature methyl ethyl ketone, 60 C water, and Jet A-1 fuel environments on the mechanical properties and microscopic failure mode of a carbon-epoxy composite laminate. Postcuring affected neither the flexural strength nor modulus of the control specimens; none of the environments affected flexural strength in either standard cure or postcured specimens. O.C.

A93-22578#
COMBUSTION OF MICROEMULSION SPRAYS
I. AHMAD and S. R. GOLLAHALLI (Oklahoma Univ., Norman) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0131) Copyright

An experimental study of the flame structure of an airblast atomized spray of a microemulsion of water and Jet-A fuel is presented. The water content of the emulsion was set at five percent by weight and the surfactant to water weight ratio was 0.7. A comparison of the results with the results of previous investigations indicate the composition of surfactant plays a strong role in the combustion characteristics of microemulsions. R.E.P.

A93-22652*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TWO AND THREE-DIMENSIONAL PREDIFFUSER COMBUSTOR STUDIES WITH AIR-WATER MIXTURE
PETER LAING, C. M. EHRESMAN, and S. N. B. MURTHY (Purdue Univ., West Lafayette, IN) Jan. 1993 19 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by GE Aircraft Engines refs
(Contract NAG3-481; DTFA03-83-A-00328)
(AIAA PAPER 93-0240) Copyright

Two- and three-dimensional gas turbine prediffuser-combustor sectors were experimentally studied under a number of mixture and flow conditions in a tunnel operating with a two-phase, air-liquid film-droplet mixture. It is concluded that water vaporization in the combustor causes changes in both local gas temperature and state of vitiation and reduces reaction rates. Substantial accumulation of water and water vapor takes place in pocket over the combustor volume, even when the air-water mixture is steady in time. The accuracy of determining combustor performance changes increases with a better knowledge of the state of the air-water mixture in the primary zone. To establish flame-out conditions it is considered to be necessary to combine the prediction of detailed flowfield and chemical activity with that of flame stability and motion characteristics. O.G.

A93-22657#
ON THE STRUCTURE AND RESPONSE OF AERODYNAMICALLY-STRAINED PLANAR PREMIXED FLAMES
C. J. SUNG and C. K. LAW (Princeton Univ., NJ) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by DOE and BP Research refs
(AIAA PAPER 93-0246) Copyright

The effects of aerodynamic straining on the structure and response of adiabatic, unrestrained, equidiffusive, planar premixed flames were investigated. The counterflow, twin-flame configuration formed by oppositely-directed identical jets of nitrogen-diluted, near-stoichiometric methane/air mixtures was studied using nonintrusive laser-based experiments and computational simulation with detailed chemistry and transport. Data obtained substantiate the concepts that the flame structure, and thereby the flame thickness, are invariant to strain rate variations for adiabatic, unrestrained, diffusionally-neutral premixed flames with complete reaction, and that these flames cannot be extinguished by straining alone. The computation results are found to be in good quantitative agreement with experimental data. O.G.

A93-23045#
ADVANCED DIAGNOSTICS FOR IN SITU MEASUREMENT OF PARTICLE FORMATION AND DEPOSITION IN THERMALLY STRESSED JET FUELS
T. J. O'HERN, W. M. TROTT, S. J. MARTIN, and E. A. KLAVETTER (Sandia National Labs., Albuquerque, NM) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by USAF refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 93-0363)

Photon-correlation spectroscopy and a quartz crystal microbalance are presently used in in situ monitoring of processes associated with the thermal degradation and solids-deposition of thermally stressed aviation fuels. It is found that significant particle formation can occur at temperatures as low as 120 C, and that relatively large particles are formed at temperatures below 200 C. An induction time is also evident in the real-time data; increasingly shorter exposure times are needed for particles to form as stress temperature is increased. O.C.

A93-23047#
CARS THERMOMETRY IN A LIQUID FUELED MODEL COMBUSTOR
J. Y. ZHU (Aerometrics, Inc., Sunnyvale, CA), T. TSURUDA, W. A. SOWA, and G. S. SAMUELSEN (California Univ., Irvine) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by General Motors Corp. refs
(Contract F08635-90-C-0100)
(AIAA PAPER 93-0366) Copyright

This paper presents non-intrusive, spatially resolved instantaneous temperature measurements in a liquid fuel fired model gas turbine can combustor using coherent anti-Stokes Raman scattering (CARS) thermometry. The objectives of this study are: (1) to demonstrate detailed single shot CARS temperature measurements in a liquid fuel fired model combustor, (2) to examine the feasibility of making reliable CARS temperature measurements in the presence of droplet induced dielectric breakdown in practical liquid fuel fired combustors, and (3) to compare the CARS measured temperature with thermocouple data to assess the reliability of these two techniques in reacting sprays. The results show that reliable CARS temperature measurements can be obtained with a signal-to-noise ratio as low as 2.5 for droplet breakdown spectra. Author

A93-23238# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SIMPLIFIED JET FUEL REACTION MECHANISM FOR LEAN BURN COMBUSTION APPLICATION
CHI-MING LEE, KRISHNA KUNDU (NASA, Lewis Research Center, Cleveland, OH), and BAHMAN GHORASHI (Cleveland State Univ.,

OH) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15504 refs
(Contract RTOP 537-01-11)
(AIAA PAPER 93-0021) Copyright

Successful modeling of combustion and emissions in gas turbine engine combustors requires an adequate description of the reaction mechanism. Detailed mechanisms contain a large number of chemical species participating simultaneously in many elementary kinetic steps. Current computational fluid dynamic models must include fuel vaporization, fuel-air mixing, chemical reactions, and complicated boundary geometries. A five-step Jet-A fuel mechanism which involves pyrolysis and subsequent oxidation of paraffin and aromatic compounds is presented. This mechanism is verified by comparing with Jet-A fuel ignition delay time experimental data, and species concentrations obtained from flametube experiments. This five-step mechanism appears to be better than the current one- and two-step mechanisms. Author

A93-23358*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PDF PREDICTION OF SUPERSONIC HYDROGEN FLAMES
P. EIFLER and W. KOLLMANN (California Univ., Davis) Jan. 1993 18 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by DAAD refs
(Contract NAG3-836)
(AIAA PAPER 93-0448) Copyright

A hybrid method for the prediction of supersonic turbulent flows with combustion is developed consisting of a second order closure for the velocity field and a multi-scalar pdf method for the local thermodynamic state. It is shown that for non-premixed flames and chemical equilibrium mixture fraction, the logarithm of the (dimensionless) density, internal energy per unit mass and the divergence of the velocity have several advantages over other sets of scalars. The closure model is applied to a supersonic non-premixed flame burning hydrogen with air supplied by a supersonic coflow and the results are compared with a limited set of experimental data. Author

N93-15686# Naval Postgraduate School, Monterey, CA.
ATOMIZATION OF JP-10/B4C GELLED SLURRY FUEL M.S. Thesis
JOHN D. GUGLIELMI Jun. 1992 49 p
(AD-A256827) Avail: CASI HC A03/MF A01

The atomization of a gelled boron slurry fuel using two commercially available airblast atomizers was studied at atmospheric pressure in non-reacting flow. The atomization of water was also characterized for comparison. Each atomizer was operated at two different liquid mass flow rates and several air/fuel ratios. Drop size distribution was measured using a Malvern 2600 HSD Laser Diffraction Particle Sizer. Drop sizes acceptable for use in ramjet combustors could be obtained for the gelled slurry fuel from both atomizers. However, this required air/fuel ratios too high for practical applications. It appears that secondary atomization methods or different types of atomizers will be required to obtain high ramjet combustion efficiencies with these fuels if they are to be used over typical ramjet operating envelopes. Author (GRA)

N93-15830*# Georgia Inst. of Tech., Atlanta. Mechanical Properties Research Lab.
DEFORMATION MECHANISMS OF NIAL CYCLICLY DEFORMED NEAR THE BRITTLE-TO-DUCTILE TRANSFORMATION TEMPERATURE Final Report
STEPHEN D. ANTOLOVICH, ASHOK SAXENA, and CHERYL CULLERS 17 Dec. 1992 49 p
(Contract NCC3-116)
(NASA-CR-191649; NAS 1.26:191649) Avail: CASI HC A03/MF A01

One of the ongoing challenges of the aerospace industry is to develop more efficient turbine engines. Greater efficiency entails reduced specific strength and larger temperature gradients, the latter of which means higher operating temperatures and increased thermal conductivity. Continued development of nickel-based superalloys has provided steady increases in engine efficiency and the limits of superalloys have probably not been realized. However, other material systems are under intense investigation for possible use in high temperature engines. Ceramic, intermetallic, and various composite systems are being explored in an effort to exploit the much higher melting temperatures of these systems. NiAl is considered a potential alternative to conventional superalloys due to its excellent oxidation resistance, low density, and high melting temperature. The fact that NiAl is the most common coating for current superalloy turbine blades is a tribute to its oxidation resistance. Its density is one-third that of typical superalloys and in most temperature ranges its thermal conductivity is twice that of common superalloys. Despite these many advantages, NiAl requires more investigation before it is ready to be used in engines. Binary NiAl in general has poor high-temperature strength and low-temperature ductility. On-going research in alloy design continues to make improvements in the high-temperature strength of NiAl. The factors controlling low temperature ductility have been identified in the last few years. Small, but reproducible ductility can now be achieved at room temperature through careful control of chemical purity and processing. But the mechanisms controlling the transition from brittle to ductile behavior are not fully understood. Research in the area of fatigue deformation can aid the development of the NiAl system in two ways. Fatigue properties must be documented and optimized before NiAl can be applied to engineering systems. More importantly though, probing the deformation mechanisms operating in fatigue will lead to a better understanding of NiAl's unique characteristics. Low cycle fatigue properties have been reported on binary NiAl in the past year, yet those studies were limited to two temperature ranges: room temperature and near 1000 K. Eventually, fatigue property data will be needed for a wide range of temperatures and compositions. The intermediate temperature range near the brittle-to-ductile transition was chosen for this study to ascertain whether the sharp change occurring in monotonic behavior also occurs under cyclic conditions. An effort was made to characterize the dislocation structures which evolved during fatigue testing and comment on their role in the deformation process. Author

N93-15931# Princeton Univ., NJ. Dept. of Mechanical and Aerospace Engineering.
CHEMICAL KINETIC AND AERODYNAMIC STRUCTURES OF FLAMES Final Report, 1 Mar. 1989 - 28 Feb. 1992
C. K. LAW 11 Jun. 1992 77 p
(Contract AF-AFOSR-0293-89)
(AD-A256015; AFOSR-92-0894TR) Avail: CASI HC A05/MF A01

The objective of the present program was to study the aerothermochemical structure of laminar premixed and nonpremixed-flames through (1) non-intrusive experimental determination in reduced and elevated pressure environments, (2) computational simulation using detailed flame and kinetic codes, and (3) asymptotic analysis with simplified and reduced mechanisms. Useful theoretical and experimental contributions were made on the determination of the burning rates and flame kinetics of the lower hydrocarbons, on the understanding of the physical and chemical parameters influencing soot formation in diffusion flames, on the identification of the role of kinetics and system non-adiabaticity in flammability limits, and on adiabatic flame stabilization. These results are relevant to the fundamental and practical issues of flame kinetics, turbulent combustion, soot formation, radiative heat transfer, flame extinction, stabilization and flammability, and supersonic combustion. GRA

N93-16389*# North Carolina State Univ., Raleigh.
MODELING OF TURBULENT SUPERSONIC H2-AIR COMBUSTION WITH AN IMPROVED JOINT BETA PDF
R. A. BAURLE and H. A. HASSAN 1991 9 p
(Contract NAG1-244; NAGW-1331)
(NASA-CR-191929; NAS 1.26:191929) Avail: CASI HC A02/MF A01

Attempts at modeling recent experiments of Cheng et al. indicated that discrepancies between theory and experiment can be a result of the form of assumed probability density function (PDF) and/or the turbulence model employed. Improvements in both the form of the assumed PDF and the turbulence model are presented. The results are again used to compare with measurements. Initial comparisons are encouraging. Author

N93-16403# Aeronautical Research Labs., Melbourne (Australia).
DEVELOPMENT OF A MENU DRIVEN MATERIALS DATA BASE FOR USE ON PERSONAL COMPUTERS: AIRCRAFT STRUCTURES TECHNICAL MEMORANDUM
R. H. KAYE Jul. 1992 36 p
(AD-A256317; ARL-STRUC-TM-584; DODA-AR-007-074) Avail: CASI HC A03/MF A01
This Memorandum presents a PC based, menu driven materials data base for the engineering related properties of advanced structural materials. General materials information and suppliers' details are also provided. Data retrieval is performed by a TURBO PASCAL program of less than 100 lines, accessing several separate text files. This program will run under most MSDOS installations. Response time and accessing time is negligible on any IBM XT (or faster) machine and a graphics adaptor is not required. GRA

N93-16537*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RELATIONSHIP BETWEEN MECHANICAL-PROPERTY AND ENERGY-ABSORPTION TRENDS FOR COMPOSITE TUBES
GARY L. FARLEY (Army Vehicle Structures Lab., Hampton, VA.) Dec. 1992 16 p
(Contract DA PROJ. 1L1-61102-AH-45; RTOP 505-63-50-08)
(NASA-TP-3284; L-17087; NAS 1.60:3284; ARL-TR-29) Avail: CASI HC A03/MF A01
U.S. Army helicopters are designed to dissipate prescribed levels of crash impact kinetic energy without compromising the integrity of the fuselage. Because of the complexity of the energy-absorption process it is imperative for designers of energy-absorbing structures to develop an in-depth understanding of how and why composite structures absorb energy. A description of the crushing modes and mechanisms of energy absorption for composite tubes and beams is presented. Three primary crushing modes of composite structures including transverse shearing, lamina bending, and local buckling are described. The experimental data presented show that fiber and matrix mechanical properties and laminate stiffness and strength mechanical properties cannot reliably predict the energy-absorption response of composite tubes. Author

N93-16637 ESDU International Ltd., London (England).
FATIGUE PROPAGATION BEHAVIOUR OF SHORT CRACKS IN TITANIUM ALLOYS Abstract Only
Nov. 1992 30 p
(ISSN 0958-0387)
(ESDU-92023; ISBN-0-85679-828-2) Avail: ESDU
ESDU 92023 discusses the different propagation behavior of short and long cracks; short cracks often do not display a threshold value of stress intensity factor range and propagate at higher rates than long cracks. The difficulties of calculating the stress intensity factor for short cracks are explained. Experimental data extracted from the literature for crack growth rate in air under constant amplitude loading are presented graphically against stress intensity factor range for 7 alloys (IMI 318, IMI 685, Ti-4Al, Ti-6Al-4V, Ti-6Al-2Sn-4Zr-6Mo, Ti-8Al, Ti-8.6Al). All the curves are derived from a number of tests except that some data for IMI 318 and Ti-8.6Al relate to individual cracks. Details of the alloy, heat treatment and mechanical properties are included, and the experimental arrangement for each set of data is indicated. For IMI 318, IMI 685 and Ti-6Al-4V, data for short and long crack growth are compared. The effect of stress ratio is shown for Ti-8Al (values of 0.1 and 0.5) and for Ti-6Al-4V (values of 0 and -1). Author

N93-16641 ESDU International Ltd., London (England).
FATIGUE PROPAGATION BEHAVIOUR OF SHORT CRACKS IN ALUMINUM ALLOYS Abstract Only
Nov. 1992 34 p
(ISSN 0958-0387)
(ESDU-92030; ISBN-0-85679-836-3) Avail: ESDU
ESDU 92030 discusses the different propagation behavior of short and long cracks; short cracks often do not display a threshold value of stress intensity factor range and propagate at higher rates than long cracks. The difficulties of calculating the stress intensity factor for short cracks are explained. Experimental data extracted from the literature for crack growth rate in air under constant amplitude loading are presented graphically against stress intensity factor range for 9 alloys (2024, 2090, 2124, 7010, 7075, 8090, 8091, RR58, an Al-Li alloy) and in vacuum and nitrogen for 7075. All the curves are derived from a number of tests except for 2124 for which data are for individual cracks. Details of the alloy, heat treatment and mechanical properties are given, and the experimental arrangement for each set of data is indicated. For all alloys, except 7010 and 7075, data for both short and long crack growth are compared, and for 2090 the effect of stress ratio variation from 0 to -2 is shown. Author

N93-17540# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
DAMAGE TOLERANCE BEHAVIOUR OF ALUMINIUM-LITHIUM SHEET ALLOYS
R. J. H. WANHILL Jun. 1991 9 p Presented at Conference on Materials Processing and Performance, Melbourne, Austalia, Sep. 1991
(NLR-TP-91244-U; ETN-92-92522) Avail: CASI HC A02/MF A01
An extensive evaluation of the damage tolerance properties of modern aluminum lithium (Al-Li) alloys is considered. The materials tested include damage tolerant tempers of the 2091 and 8090 alloy, and the high strength 2090 alloy. These were compared with conventional and widely used damage tolerant 2024-T3 alloy and the high strength 7075-T6 alloy. Qualification of Al-Li alloys for aerospace structures emphasizes the fracture and fatigue crack growth properties in the in-service inspectable damage tolerance regime. Fracture toughnesses, crack resistances, and fatigue crack growth properties of Al-Li and conventional sheet alloys were determined. The practical significance of the results is discussed, and the current status of Al-Li sheet alloys is indicated. A survey of a comprehensive qualification program that includes other properties besides those related to damage tolerance is included. ESA

N93-17614# Instituto Superior Tecnico, Lisbon (Portugal). Dept. of Mechanical Engineering.
EXPERIMENTAL ANALYSIS OF COMBUSTION OSCILLATIONS WITH REFERENCE TO RAMJET PROPULSION
M. N. R. NINA and G. P. A. PITA *In* AGARD, Airbreathing Propulsion for Missiles andProjectiles 8 p Sep. 1992
Copyright Avail: CASI HC A02/MF A03
The influences of flow rate, fuel air ratio, and bluff body geometry on the predominant frequencies of combustion-driven oscillations were measured in a tube and disc combustor. Small shifts in major frequencies were observed for different stabilizer geometries. By changing mass flow rate and at high velocities by changing the F/A ratio, discrete jumps in the frequency of large amplitude oscillations were produced in some of the configurations. Measurements of the wall pressure oscillations amplitude along the cold duct, upstream from the flameholder, confirm the presence of an acoustic three quarter wave. Changes in the cold cut length implies a difference in the main frequency of the pressure oscillations spectrum that was found to agree with the difference between two acoustic 3/4 waves corresponding to the two tube lengths. Author

N93-17676# Naval Postgraduate School, Monterey, CA.
X RAY DIFFRACTION AND ELECTRON MICROSCOPE STUDIES OF YTTRIA STABILIZED ZIRCONIA (YSZ) CERAMIC

COATINGS EXPOSED TO VANADIA M.S. Thesis
KOSTANDINOS G. KONDOS Sep. 1992 52 p
(AD-A258055) Avail: CASI HC A04/MF A01

The U.S. Navy sometimes has the requirement to use low cost fuels containing significant amounts of vanadium and sulfur in gas turbine engines. Unfortunately the yttria stabilized zirconia (YSZ) which is used as a thermal barrier coating on gas turbine blades can be severely attacked by vanadia. Powders of YSZ containing 8-mol percent Y2O3 and pure zirconia containing various and mounts Of V2O5 were annealed at 900 C. These were then examined by x-ray diffraction and electron microscopy, as well as single crystals of pure Zro2 and YSZ (20 wt percent Y2O3) exposed to V2O5 melts, to study how the vanadia degrades the YSZ by reacting with the stabilizer to form YVO4 and how the vanadium transforms the cubic and tetragonal YSZ crystal structures to monoclinic which degrades rapidly as a gas turbine blade coating. GRA

N93-17693# Naval Postgraduate School, Monterey, CA.
IR IMAGING FOR COMBUSTION CHARACTERISTICS AND OPTICAL PROPERTIES OF BORON/BORON OXIDE M.S. Thesis
YANG JEN-CHENG Jun. 1992 42 p
(AD-A257747) Avail: CASI HC A03/MF A01

An experimental investigation was conducted to determine if a new high speed IR microscope could be used to study the ignition and combustion characteristics of boron/boron carbide and to measure the particle emissivity as a function of temperature. Air heater limitations did not permit the investigation of ignition characteristics. Emissivity in the 2-5 micron band was measured as a function of temperature using a small boron filament. Data obtained using different IR band-pass filters resulted in significantly different results due to the apparent dependence of the emissivity of boron oxide on both temperature and wavelength. It was also found that care must be used to insure that the entire image is in sharp focus and that a means must be provided for measuring an accurate surface temperature. GRA

N93-17704# Pratt and Whitney Aircraft, West Palm Beach, FL. Government Engines and Space Propulsion.
FATIGUE IN SINGLE CRYSTAL NICKEL SUPERALLOYS Technical Progress Report, 16 Sep. - 15 Oct. 1992
CHARLES ANNIS 15 Oct. 1992 7 p
(Contract N00014-91-C-0124)
(AD-A258038; PW/FR21998-12) Avail: CASI HC A02/MF A01

This program investigates the seemingly unusual behavior of single crystal airfoil materials. The fatigue initiation processes in single crystal (SC) materials are significantly more complicated and involved than fatigue initiation and subsequent behavior of a (single) macrocrack in conventional isotropic materials. The understanding of these differences is the major goal of this project. GRA

N93-17746# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
DIRECT NUMERICAL SIMULATION OF COMBUSTION IN TURBULENT SUPERSONIC FLOW [SIMULATION NUMERIQUE DIRECTE DE COMBUSTION EN ECOULEMENT SUPERSONIQUE TURBULENT]
R. J. GATHMANN (Institut de Mecanique de Grenoble, France) and J. P. CHOLLET 1991 4 p In FRENCH Presented at 10th Congres Francais de Mecanique, Paris, France, 2-6 Sep. 1991
(DS-2138; ETN-93-93385) Avail: CASI HC A01/MF A01

The numerical code SERAC (French acronym for simulation of reactive flow for combustion applications) is presented. The turbulent combustion flow encompasses complex dynamic, thermodynamic and chemical kinetic interactions. The application of the code to simulate combustion in a confined mixing layer which represents the flow in a scramjet propulsion system is addressed. The code is also applied to simulate the three dimensional roundjet flow under periodic pressure also associated with supersonic aircraft propulsion. ESA

N93-17852# Societe Nationale d'Etude et de Construction de Moteurs d'Aviation, Moissy-Cramayel (France).
THE BETA-CEZ, A NEW HIGH PERFORMANCE TITANIUM ALLOY FOR AEROSPACE ENGINES
B. CHAMPIN, B. PRANDI, P. E. MOSSER, and Y. HONNORAT 1991 22 p In FRENCH Presented at AAAF 39th Salon International de Paris on 'Materiaux pour l'Aeronautique', Le Bourget, France, 14-23 Jun. 1991
(DS-2022; ETN-93-93392) Avail: CASI HC A03/MF A01

The different steps in the development of beta-CEZ alloy are described: chemistry optimization and melting; behavior during deformation and forging; microstructure evolution during thermomechanical treatments and adjustment of the compromise between hardness and toughness; mechanical characterization of a forged roller (tensile tests, creep properties, toughness measurements, low cycle fatigue, crack propagation rate). It is concluded that the forging microstructure of rollers is slightly less ductile than that of optimized bars. Modification of heat treatment has been required leading to lower values of strength (mainly at room temperature). However compared to Ti17, (alloy of the same category), the beta-CEZ grade exhibits at least as good characteristics, with improvement in tensile creep and fatigue resistance. ESA

N93-17920*# National Aerospace Lab., Amsterdam (Netherlands). Structures and Materials Div.
INTERLAMINAR STRESS ANALYSIS AT THE SKIN/STIFFENER INTERFACE OF A GRID-STIFFENED COMPOSITE PANEL
J. F. M. WIGGENRAAD and N. R. BAULD, JR. (Deutsche Sporthochschule, Cologne, Germany) 8 Jan. 1991 26 p Presented at 6th International Conference on Composite Structures, Paisley, Scotland, 9-11 Sep. 1991
(Contract NAS1-17925)
(NASA-CR-192177; NAS 1.26:192177; NLR-TP-91011-U; ETN-92-92512) Avail: CASI HC A03/MF A01

Results of an analysis of the interlaminar stress components at the skin wrap, skin core, and wrap core interfaces for an advanced concept stiffened panel, using a global/local finite element procedure are presented. The procedure consists of a global model of two dimensional shell elements that is used to design a grid stiffened panel with blade type stiffeners, a local model of three dimensional solid elements that is used to compute interlaminar stress components, and a scene devised to assign displacement boundary conditions for the local model that are derived from displacement and rotation data of a few nodes of the global model. The influence of various design parameters on the interlaminar stress was studied. The parameters considered were limited to those for which the global model solution was not affected. The interlaminar stresses for this panel design were found to be well below typical tensile normal and shearing strengths of a graphite epoxy material. ESA

N93-18242# Dayton Univ., OH. Research Inst.
A CONDENSED PHASE TEST CELL ASSEMBLY FOR THE SYSTEM FOR THERMAL DIAGNOSTIC STUDIES (STDS) Final Report, Jun. 1990 - Dec. 1991
RICHARD C. STRIEBICH and W. A. RUBEY Aug. 1992 64 p
(Contract F33615-90-C-2047)
(AD-A258463; WL-TR-92-2040) Avail: CASI HC A04/MF A01

A reactor and its associated peripherals were designed to be an integral part of the System for Thermal Diagnostic Studies (STDS), a versatile mainframe thermal system. The Condensed Phase Test Cell (CPTC) can be used to conduct experiments for flowing liquids at temperatures up to approximately 800 C and pressures up to 1500 psig. In the area of thermal stability, the CPTC can be used to conduct flowing experiments on jet fuels, jet fuel candidates, and model mixtures at both subcritical and supercritical conditions. By subjecting condensed phase liquids to controlled conditions of temperature, pressures, reactive atmosphere (dissolved oxygen concentration), residence time, and distribution, etc., thermal degradation experiments could be conducted. Product distributions from the exposure of liquid phase

and condensed phase material were performed via high pressure liquid sampling valves in line with gas chromatography-mass spectrometry (GC-MS); thus, technique is capable of measuring dissolved fixed gases (nitrogen, oxygen, argon, carbon dioxide, etc.), cracking gases (methane, ethane, ethylene, propylene, etc.) and thermal reaction products of the parent material. GRA

N93-18537# Oak Ridge National Lab., TN.
MATERIALS DEVELOPMENT PROGRAM, CERAMIC TECHNOLOGY PROJECT ADDENDUM TO PROGRAM PLAN: COST EFFECTIVE CERAMICS FOR HEAT ENGINES
Aug. 1992 25 p
(Contract DE-AC05-84OR-21400)
(DE93-003663; ORNL/M-2309) Avail: CASI HC A03/MF A01

This is a new thrust in the Ceramic Technology project. This effort represents an expansion of the program and an extension through FY 1997. Moderate temperature applications in conventional automobile and truck engines will be included along with high-temp. gas turbine and low heat rejection diesel engines. The reliability goals are expected to be met on schedule by end of FY 1993. Ceramic turbine rotors have been run (in DOE's ATTAP program) for 1000 h at 1370 C and full speed. However, the cost of ceramic components is a deterrrent to near-term commercialization. A systematic approach to reducing this cost includes the following elements: economic cost modeling, ceramic machining, powder synthesis, alternative forming and densification processes, yield improvement, system design studies, standards development, and testing and data base development. A draft funding plan is outlined. DOE

N93-18784*# Ohio State Univ., Cleveland. Dept. of Materials Science and Engineering.
COMPATIBILITY OF POTENTIAL REINFORCING CERAMICS WITH NI AND FE ALUMINIDES Final Technical Report
WILLIAM A. T. CLARK and JEFFREY A. MOSER 10 Dec. 1991 6 p
(Contract NAG3-942)
(NASA-CR-192232; NAS 1.26:192232) Avail: CASI HC A02/MF A01

There is a great deal of interest in the possible utilization of intermetallic compounds in advanced high temperature gas turbine engines. These compounds exhibit a variety of promising properties, including reasonable strength, high melting points, relatively low densities, and good corrosion resistance. However, in general, they also show limited ductilities and toughness, and less than optimum creep strengths at elevated temperatures. In addition, in applications involving advanced gas turbine engines, it is often necessary for candidate materials to have large elastic moduli. The present study is part of a program whose objective is to identify a high temperature fiber reinforced composite. The approach adopted was to fabricate laboratory samples of the combinations of materials considered by Misra, in order to determine the extent to which the thermodynamic calculations can predict phase stability. As many of the ceramic phases considered are not currently available in fiber form, they were added as particulates to the alloy matrices. The ways in which the materials were produced and evaluated are described. Author

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ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

A93-17569
GEOMETRICALLY NONLINEAR LOCAL FLUTTER ANALYSIS OF SUPERSONIC AIRPLANE SKIN PLATES IN THE POTENTIAL SUPERSONIC FLOW
A. OLEJNIK (Military Technical Academy, Warsaw, Poland) Zagadnienia Drgan Nieliniowych (ISSN 0044-1597) no. 24 1992 p. 223-235. refs
(ISBN 83-01-10939-4) Copyright

In the paper the problem of nonlinear vibrations of plates in supersonic flow has been solved. Equations of motion for a plate element were derived from Hamilton's principle. For discretization of the plate domain, the triangle element with 18 DOFs in the corner node has been applied. Solutions of the nonlinear eigenvalue problem have been done by means of an algorithm of inverse iteration modified for this purpose. Good agreement with the results obtained by means of analytical methods proves the correctness of the applied algorithms and derived computer programs. Author

A93-17727
ACTUATION STRAIN DECOUPLING THROUGH ENHANCED DIRECTIONAL ATTACHMENT IN PLATES AND AERODYNAMIC SURFACES
RON BARRETT (Kansas Univ., Lawrence) *In* European Conference on Smart Structures and Materials, 1st, Glasgow, United Kingdom, May 12-14, 1992, Proceedings Orsay, France/Bellingham, WA/Bristol, United Kingdom European Optical Society/Society of Photo-Optical Instrumentation Engineers/Institute of Physics 1992 p. 383-386. refs
Copyright

Three methods of decoupling and one method of increasing actuator strain through enhanced directional attachment (EDA) are presented. Directionally attached piezoeletric (DAP) elements are laminated to an uncoupled plate to generate 44 deg/m in bending without twist and 31 deg/m of twist without bending. The strains are enhanced 5 to 12 percent when the elements are transversely stiffened. Analytical EDAP models are presented with experiment and theory in close agreement. A comparison of EDA to current laminating techniques demonstrates 50 to 1000 percent higher strain rates in twist. Data from a wing using EDAP elements is also briefly summarized. Author

A93-17762
MISALIGNMENTS OF AIRBORNE LASER BEAMS DUE TO MECHANICAL VIBRATIONS
J. C. FREITAS, M. A. ABREU, F. C. RODRIGUES, and FERNANDO D. CARVALHO (Lab. Nacional de Engenharia e Tecnologia Industrial, Lisbon, Portugal) *In* Optical systems in adverse environments; Proceedings of the Meeting, Singapore, Oct. 22-27, 1990 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 42-48. refs
Copyright

The effect of mechanical vibrations on the shape characteristics and direction of a laser beam of a particular spectrum of vibration is considered. A detection system designed to collect laser pulses emitted by a pulsed laser diode placed onboard of a jet airplane is simulated experimentally. Results show that the area illuminated by a laser beam can vary quite diversely with the frequency and amplitude of the vibration over the period of detection producing a divergence of the laser beam different from that of a static emitter. O.G.

A93-17765
APPLICATIONS OF LASER TECHNIQUES IN FLUID MECHANICS
W. K. CHAN, C. Y. LIU, and Y. W. WONG (Nanyang Technological Inst., Singapore) *In* Optical systems in adverse environments; Proceedings of the Meeting, Singapore, Oct. 22-27, 1990 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 82-89. refs
Copyright
Three examples of different applications of laser techniques in experimental fluid mechanics are described including flow field around a proposed heart prostheses, flow field around a model motor vehicle, and flow visualization of the vortex shedding from a delta wing. Velocity measurements of flow around the heart valve prosthesis indicate that the new design is capable of delaying flow separation. Velocity measurements of flow around a model motor vehicle show that separation occurs above the bonnet and at the rear of the vehicle. O.G.

A93-17767
AUTONOMOUS MOBILE LASER COMPLEX
I. KH. FAKHRUTDINOV, A. P. AVDOSHIN, IU. N. MOSHIN, and V. V. POLTAVSKII (Kazan Engine Plant 'Soiuz', Russia) *In* Optical systems in adverse environments; Proceedings of the Meeting, Singapore, Oct. 22-27, 1990 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 98-106.
Copyright
An autonomous mobile laser complex design is described which is based on a gas dynamic laser and airplane jet-propulsion engines as a compressed air source. The advantages of this laser complex include the possibility of performing unique operations, long duration operation of the complex in a self-contained mode, and remotely operated treatment. O.G.

A93-17862
DETECTION AND PARAMETER ESTIMATION OF ATMOSPHERIC TURBULENCE BY GROUND-BASED AND AIRBORNE CO2 DOPPLER LIDARS
G. A. POGOSOV (Inst. of Aircraft Equipment, Zhukovski, Russia), S. A. AKHMANOV, V. M. GORDIENKO (Moscow State Univ., Russia), L. A. KOSOVSKII (Inst. of Aircraft Equipment, Zhukovski, Russia), N. N. KUROCHKIN, and A. V. PRIESSHEV (Moscow State Univ., Russia) *In* Laser radar VI; Proceedings of the Meeting, Los Angeles, CA, Jan. 23-25, 1991 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 115-124. refs
Copyright
Potentials of ground-based and of airborne CO2 Doppler lidars are discussed in relation to the problems of long range detection and parameters estimation of atmospheric turbulence. Our experience to use such systems working in CW and quasipulsed regimes is reviewed. A new method for the measurement of the C sub V-sq constant in turbulent atmosphere with a CW CO2 Doppler lidar is presented. Author

A93-18054
A COMPARISON OF THE DRAG-REDUCING BENEFITS OF RIBLETS IN INTERNAL AND EXTERNAL FLOWS
J. J. ROHR, G. W. ANDERSEN, L. W. REIDY, and E. W. HENDRICKS (U.S. Navy, Naval Ocean Systems Center, San Diego, CA) Experiments in Fluids (ISSN 0723-4864) vol. 13, no. 6 1992 p. 361-368. Research supported by U.S. Navy refs
Copyright
Equivalent drag-reducing performance is observed with 3M riblets in fully developed internal (pipe) and developing external (flat plate) flows. Drag reduction begins around h(+) = 3, peaks between 6 and 9 percent at about h(+) = 12, and becomes zero for a value of h(+) between 20 and 30. In laminar pipe flow no significant change in drag is observed with the 3M riblets present. At high Reynolds numbers, after exhibiting fully rough behavior, friction factors for the 3M riblets are observed to monotonically decrease with increasing Reynolds number. Author

A93-18243
INTEGRAL EQUATIONS IN THE PROBLEM OF FLOW PAST AN AIRFOIL [OB INTEGRAL'NYKH URAVNENIIAKH ZADACHI OBTEKANIIA PROFILIA]
D. N. GORELOV Rossiiskaia Akademiia Nauk, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 4 July-Aug. 1992 p. 173-177. In Russian. refs
Copyright
Boundary value problems of flow past an airfoil are usually reduced to the solution of singular integral equations which generally have a parametric singularity. Here a system of integral equations for the tangential velocity components on the upper and lower sides of the airfoil is obtained which has no parametric singularity. The use of the discrete vortex method for the efficient solution of these equations is illustrated by an example. V.L.

A93-18326
IMPROVEMENT OF AIRCRAFT MAINTENANCE METHODS [SOVERSHENSTVOVANIE METODOV EKSPLUATATSII LETATEL'NYKH APPARATOV]
N. I. VLADIMIROV, ED. (Rizhskii Inst. Inzhenerov Grazhdanskoi Aviatsii, Riga, Latvia) Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 155 p. In Russian.
Copyright
The papers presented in this volume provide an overview of recent theoretical and experimental research aimed at improving the maintenance of aircraft, developing advanced diagnostic techniques, and increasing the efficiency and safety of flight operations. Topics discussed include design characteristics of the functional systems of aircraft and prediction of their technical condition, a probability analysis of a method for diagnosing gas turbine engines on the basis of thermogasdynamic parameters, characteristics of fatigue crack growth under the service-spectrum loading of the tail boom, and the accuracy of nonparametric reliability estimates under varying operation conditions. Papers are also presented on ways of reducing the aeration of hydraulic fluids in aircraft, evaluation of the efficiency of the pilot's control activity in a flight simulator, and using control charts for the analysis of the performance of aviation specialists. (For individual items see A93-18327 to A93-18351) V.L.

A93-18329
SELECTION OF METHODS AND EQUIPMENT FOR MONITORING THE TECHNICAL CONDITION OF BOOSTER SYSTEM COMPONENTS [VYBOR METODOV I SREDSTV KONTROLIA TEKHNICHESKOGO SOSTOIANIIA AGREGATOV BUSTERNYKH SISTEM]
I. I. MININ, I. S. SHUMILOV, A. V. MILTO, Z. I. RUTKOVSKAIA, and N. P. KUZNETSOV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 11-14. In Russian. refs
Copyright
Methods for monitoring and diagnosing the principal faults of the components of aircraft booster systems are examined. The diagnostic equipment is selected on the basis of an analysis of the principal types of faults. Results of experimental studies concerned with booster system diagnostics are presented. V.L.

A93-18335
A METHOD FOR EVALUATING THE TECHNICAL CONDITION OF HYDRAULIC CONTROL BOOSTERS WITHOUT THEIR DISASSEMBLY [METOD BEZRAZBORNOI OTSENKI TEKHNICHESKOGO SOSTOIANIIA GIDROUSILITELEI]
IU. M. KOTOLEVSKII *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 40-43. In Russian. refs
Copyright
A method is proposed for evaluating the condition of hydraulic boosters and assessing the need for repairs directly on the aircraft or on a special test bench without the full disassembly of the booster. The method is based on measuring the mismatch between the input and output signal as a generalized diagnostic parameter

reflecting the characteristic properties of hydraulic boosters. Results of an experimental validation of the method are presented. V.L.

A93-18343
ACCURACY OF NONPARAMETRIC RELIABILITY ESTIMATES UNDER VARYING OPERATION CONDITIONS [O TOCHNOSTI NEPARAMETRICHEKSIKH OTSENOK NADEZHNOSTI PRI RAZNORODNYKH USLOVIIAKH EKSPLUATATSII]
V. L. RASTRIGIN and Z. A. SHUL'KIN *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1990 p. 83-87. In Russian. refs
Copyright
Nonparametric estimates of reliability indices are examined, and the accuracy of these estimates is evaluated for varying operation conditions. It is shown that the use of traditional methods of statistical estimation leads to the overestimation of reliability in typical situations. A method is proposed whereby the resulting error can be reduced through a more adequate calculation of the accrued hours of operation. V.L.

A93-18360
DIAGNOSTICS OF THE HYDRAULIC SYSTEM OF TU-204 AIRCRAFT [DIAGNOSTIKA GIDROSISTEM VOZDUSHNYKH SUDOV TIPA TU-204]
A. V. MILTO, E. I. RUTKOVSKAIA, V. V. BUZENKOV, N. P. KUZNETSOV, and A. S. CHERENKOV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 37-41. In Russian. refs
Copyright
An optimal list of diagnostic parameters and their measurement ranges have been developed for the hydraulic system of the Tu-204 aircraft as the basis for improving the measuring instrumentation. Algorithms and methods for the diagnostics of the Tu-204 hydraulic system have been developed and tested. The general design of a newly developed diagnostic system for the Tu-204 hydraulic system is described. V.L.

A93-18370
CRACK GROWTH UNDER CONDITIONS OF SERVICE LOADING [ROST TRESHCHINY V USLOVIIAKH EKSPLUATATSIONNOGO NAGRUZHENIIA]
A. A. KONDRAT'EV, V. P. PAVELKO, and O. S. POPOV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 84-87. In Russian. refs
Copyright
Data are presented on the conditions of a flight experiment aimed at the study of fracture toughness characteristics using crack growth indicators. Crack growth in a wing center section panel is considered as an example. Preliminary quantitative estimates of the parameters of a kinetic fracture diagram are obtained. V.L.

A93-18371
IMPROVEMENT OF ROTATING BRUSHES FOR SURFACE CLEANING [USOVERSHENSTVOVANIE ROTORNYKH SHCHETOK DLIA OCHISTKI POVERKHNOSTEI]
E. S. BARYSHEV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 88-93. In Russian. refs
Copyright
The general design, operation, and performance characteristics of the currently used aircraft-washing machines are briefly reviewed, and areas that need improvement are identified. In particular, specific recommendations are given concerning the improvement of the design of rotating brushes as one of the possible ways of improving the efficiency of mechanized washing. V.L.

A93-18611
COHERENT X-RAY IMAGING FOR CORROSION EVALUATION - A PRELIMINARY ASSESSMENT
LARRY LAWSON (Northwestern Univ., Evanston, IL) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11A; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 315-322. Research supported by FAA refs
(Contract W-7405-ENG-82)
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When a layered joint corrodes, the X-ray transmissivity may either be enhanced by material thinning or reduced by corrosion-product accumulation; it may also remain constant. A framework is presented for the X-ray scattering measurement of corrosion in cases where transmission measurements would be subject to uncertainties. A comparison is conducted between Compton backscatter and coherent-imaging modalities; the statistics thus far obtained for these are inconclusive, although both appear to be feasible. O.C.

A93-18618
CORRELATION OF X-RAY CT MEASUREMENTS TO SHEAR STRENGTH IN PULTRUDED COMPOSITE MATERIALS
G. GEORGESON, R. BOSSI, L. O'DELL, G. LORSBACH, and J. NELSON (Boeing Co., Seattle, WA) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11A; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 395-402. Research sponsored by USAF
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X-ray computed tomography (CT) NDE data measuring material density/composite constituents, which are displayed as a map of the relative linear X-ray attenuation coefficients of small-volume elements in a cross-section of the sample, can be quantitatively employed for measuring consolidation in pultruded composites. Such CT values are presently noted to correlate to shear strength for a given matrix-resin and various pultrusion-process variables. O.C.

A93-18619
MEASUREMENT OF THE CENTER-OF-GRAVITY USING X-RAY COMPUTED TOMOGRAPHY
R. BOSSI, A. CREWS, and J. NELSON (Boeing Defense & Space Group, Seattle, WA) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11A; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 403-408.
(Contract F33615-88-C-5404)
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The experimental results presented indicate that it is technically feasible to employ X-ray CT data for center-of-gravity (CG) calculations, as in the present case of a ring-test phantom. The method's accuracy is noted to be better than 0.8 g-cm for homogeneous materials; while accuracy is reduced for nonhomogeneous materials, the results have validity within specifiable constraints. The position of CGs can be determined to about 1/10,000 of the part diameter; and the method is applicable to parts of complex geometry. O.C.

A93-18627* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPARISON OF HEATING PROTOCOLS FOR DETECTION OF DISBONDS IN LAP JOINTS
WILLIAM P. WINFREE (NASA, Langley Research Center, Hampton, VA), B. S. CREWS, and P. A. HOWELL (Analytical Services and Materials, Inc.; NASA, Langley Research Center, Hampton, VA) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11A; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 471-478. refs
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A thermographic technique is presented which is shown to be effective for disbond detection in lap-joint samples. The study of various heating protocols shows that shorter heating times allow the greatest contrast in smaller disbonds; the optimum heating technique for this case is periodic heating. In order to compare the different heating protocols, contrast is defined as a function of the moments of the histograms for the bonded region and

unbonded regions of the reduced thermal images. A comparison of the bonded-unbonded contrast for different heating times establishes the parameters which maximize disbond detection probability. O.C.

A93-18652

COMPARISON OF NEURAL NETWORK AND MARKOV RANDOM FIELD IMAGE SEGMENTATION TECHNIQUES

FRED G. SMITH, KAREN R. JEPSEN, and PETER F. LICHTENWALNER (McDonnell Aircraft Co., Saint Louis, MO) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11A; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 717-724. refs

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Two NDE image-processing technologies are discussed: (1) a neural-network-based defect location technique which requires further refinement but promises to yield a viable image-analysis algorithm, and (2) the Markov random field (MRF) image-segmentation techniques, which are more complex than neural networks but useful in areas where neural network performance is weak. Manufacturing applications that must be implemented with minimal effort may benefit from neural networks; if image segmentation with minimum probability of error is required, MRF algorithms may be preferable. O.C.

A93-18670* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

IMAGING FLAWS IN THIN METAL PLATES USING A MAGNETO-OPTIC DEVICE

B. WINCHESKI, D. R. PRABHU (NASA, Langley Research Center; AS&M, Inc., Hampton, VA), M. NAMKUNG (NASA, Langley Research Center, Hampton, VA), and E. A. BIRT (NASA, Langley Research Center; AS&M, Inc., Hampton, VA) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11A; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 871-878. refs

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An account is given of the capabilities of the magnetooptic/eddy-current imager (MEI) apparatus in the case of aging aircraft structure-type flaws in 2024-T3 Al alloy plates. Attention is given to images of cyclically grown fatigue cracks from rivetted joints in fabricated lap-joint structures, electrical discharge machining notches, and corrosion spots. Although conventional eddy-current methods could have been used, the speed and ease of MEI's use in these tests is unmatched by such means. Results are displayed in real time as a test piece is scanned, furnishing easily interpreted flaw images. O.C.

A93-18752* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

HEAT TRANSFER PERFORMANCE COMPARISONS OF FIVE DIFFERENT RECTANGULAR CHANNELS WITH PARALLEL ANGLED RIBS

J. S. PARK, J. C. HAN, Y. HUANG, S. OU (Texas A & M Univ., College Station), and R. J. BOYLE (NASA, Lewis Research Center, Cleveland, OH) International Journal of Heat and Mass Transfer (ISSN 0017-9310) vol. 35, no. 11 Nov. 1992 p. 2891-2903. refs

(Contract NAG3-311; NAS3-24227)

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This paper systematically presents the results of heat transfer and friction factor data measured in five short rectangular channels with turbulence promoters. The project investigated the combined effects of the channel aspect ratio, rib angle-of-attack, and flow Reynolds number on heat transfer and pressure drop in rectangular channels with two opposite ribbed walls. The channel aspect ratio (width-to-height, W/H, ribs on side W) varied from 1/4 to 1/2, to 1, 2, and 4, while the corresponding rib angles-of-attack alpha were 90 deg, 60 deg, 45 deg, and 30 deg, respectively. The Reynolds number range was 10,000-60,000. The results suggest that the narrow aspect ratio channels (W/H less than 1) give much better heat transfer performance than the wide aspect ratio channels (W/H greater than 1). For the square channel (W/H = 1), the 60 deg/45 deg angled ribs provide the best heat transfer performance. For the narrow aspect ratio channel (W/H = 1/4 or 1/2), the 45 deg/60 deg angled ribs are recommended, while the 30 deg/45 deg angled ribs are better for wide aspect ratio channels (W/H = 4 or 2). Author

A93-18789

VERY HIGH RELIABILITY - COST AND CONSEQUENCES

J. T. PROFFITT (Ministry of Defence, London, United Kingdom) *In* Aero engine reliability, integrity and safety; Proceedings of the Conference, Bristol, United Kingdom, Oct. 17, 18, 1991 London Royal Aeronautical Society 1991 p. 11.1-11.7.

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The present exploration of the broader implications of the achievement of highly reliable and easily maintained military aircraft engines gives attention to relative savings and costs, as well as the organizational effects of such high reliability. Reliability-related savings that can be achieved only by doing something differently may involve additional costs in the short term. The bases for formulation of realistic reliability targets are discussed in clear view of the organizational changes that must be instituted. O.C.

A93-18978

SOLVING PROBLEMS WITH SINGULARITIES USING CONFORMAL MAPPINGS

G. L. LUTTER (McDonnell Douglas Space Systems Co., Huntington Beach, CA) and O. OHTMER (California State Univ., Long Beach) *In* Struceng & Femcad - Structural engineering and optimization Gournay-sur-Marne, France Institute for Industrial Technology Transfer-International 1991 p. 27-39. refs

Procedures are described for solving problems with singularities by means of conformal mappings. For 2D boundary value problems with sharp corners and large curvatures of the boundary curve, the boundary is smoothed first by applying conformal mappings, thereby deleting the singularities at the corner points. The procedure can be also applied for cracks in three dimensions, solving a modified boundary value problem for the transformed shape. Afer obtaining a smooth curve or a smooth surface for the 2D or 3D problems, respectively, the Dirichlet and Neumann integral equations with mixed boundary conditions are solved using a spline approach, whereby the kernel of the integral equation is approximated by spline functions using a Gauss-elimination method. The numerical integration is performed by very accurate formulas, using the first and the second derivatives. The final governing linear system is solved by the orthogonal decomposition method. I.S.

A93-18989

STRUCTURAL ANALYSIS OF A NONLINEAR PROBLEM OF AEROELASTICITY FOR CFC STRUCTURES

RADOLJUB TOMIC (Soko Aircraft Industries, Mostar, Yugoslavia) *In* Struceng & Femcad - Structural engineering and optimization Gournay-sur-Marne, France Institute for Industrial Technology Transfer-International 1991 p. 217-223. refs

Solutions are obtained for a system of nonlinear algebraic equations based on FEM, using an appropriate increment/iteration method. Structural parameters are calculated for a structural model of a carbon-fiber-composite aerodynamic surface subjected to known loading. It is shown that the selection of finite elements and corresponding system equations depends on the nature of the problem, the geometric and material properties of the structure, external influences, the nature of nonlinear behavior, and the applied type of discretization. I.S.

A93-19141

NONLINEAR RESPONSE OF A CLAMPED BEAM AND PLATE TO HIGH LEVELS OF EXCITATION

HOWARD F. WOLFE (USAF, Flight Dynamics Directorate, Wright-Patterson AFB, OH) and ROBERT G. WHITE (Southampton Univ., United Kingdom) *In* DGLR/AIAA Aeroacoustics Conference,

14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 117-122. refs

Acoustic fatigue failure in aerospace structures has been a concern for many years. New prediction techniques are needed for the new materials and structural concepts of interest and higher sound pressure levels encountered for the hypersonic flight regime. The objective of this program of work is to improve the fundamental understanding of the nonlinear behavior of beams and plates excited from low to high levels of excitation. Experiments have been conducted utilizing a clamped-clamped (C-C) beam statically tested and shaker driven at increasing levels of excitation. Similarly, a C-C-C-C plate was acoustically excited in a progressive wave tube. The total strains and the components, bending and axial, were measured for increasing levels of excitation. The bending strain response modes induced exhibited a peak broadening and frequency increase with an increase in excitation levels. The bending strain amplitudes were slightly less than the total strains measured. While the axial strains increased with increasing excitation levels, they did not increase as rapidly as expected. The static test resulted in a linear relationship between the strain and the loads over the level of interest. The dynamic tests resulted in a nonlinear relationship between the response strains and the excitation levels. Author

A93-19157* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

INSTABILITY OF RECTANGULAR JETS

CHRISTOPHER K. W. TAM and ANDREW T. THIES (Florida State Univ., Tallahassee) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 279-286. refs
(Contract NAG1-421)

The instability of rectangular jets is investigated using a vortex sheet model. It is shown that such jets support four linearly independent families of instability waves. Within each family there are infinitely many modes. A way to classify these modes according to the characteristics of their mode shapes or eigenfunctions is proposed. A parametric study of the instability wave characteristics has been carried out. A sample of the numerical results is reported here. It is found that the first and third modes of each instability wave family are corner modes. The pressure fluctuations associated with these instability waves are localized near the corners of the jet. The second mode, however, is a center mode with maximum fluctuations concentrated in the central portion of the jet flow. The center mode has the largest spatial growth rate. It is anticipated that as the instability waves propagate downstream the center mode would emerge as the dominant instability of the jet. Author

A93-19173* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

NONLINEAR VIBRATION AND RADIATION FROM A PANEL WITH TRANSITION TO CHAOS INDUCED BY ACOUSTIC WAVES

LUCIO MAESTRELLO (NASA, Langley Research Center, Hampton, VA), ABDELKADER FRENDI (Analytical Services and Materials, Inc., Hampton, VA), and DONALD E. BROWN (Lockheed Engineering and Sciences Co., Hampton, VA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 409-420. refs
(Contract NAS1-19317; NAS1-19000)

The dynamic response of an aircraft panel forced at resonance and off-resonance by plane acoustic waves at normal incidence is investigated experimentally and numerically. Linear, nonlinear (period doubling) and chaotic responses are obtained by increasing the sound pressure level of the excitation. The response time history is sensitive to the input level and to the frequency of excitation. The change in response behavior is due to a change in input conditions, triggered either naturally or by modulation of the bandwidth of the incident waves. Off-resonance, bifurcation is diffused and difficult to maintain, thus the panel response drifts into a linear behavior. The acoustic pressure emanated by the panel is either linear or nonlinear as is the vibration response. The nonlinear effects accumulate during the propagation with distance. Results are also obtained on the control of the panel response using damping tape on aluminum panel and using a graphite epoxy panel having the same size and weight. Good agreement is obtained between the experimental and numerical results. Author

A93-19189

NOISE EVALUATION OF LIGHT PROPELLER-DRIVEN AIRCRAFT

PER V. BRUEL (Bruel & Kjaer, Naerum, Denmark) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 615-622. refs

A proposal for a new method of measuring light propeller-driven aircraft put forward by ICAO (Chapter 10 in Annex 16) is described. The primary changes from the present procedure are that the microphone is placed on the ground and that the aircraft is evaluated under climb conditions. A series of measurements is reported using both methods for the same type of aircraft. On the basis of these measurements, a final proposal is advanced for a method of obtaining a very high degree of accuracy by using four simple independent measurement stations when making measurements for aircraft certification purposes. The Chapter 10 method is found to produce more accurate results than by using the former Chapter 6 method. The difference in the sound pressure being measured by the same aircraft is also determined with reasonable certainty. C.A.B.

A93-19193

THE CRITICAL ROLE OF TURBULENCE MODELING IN THE PREDICTION OF SUPERSONIC JET STRUCTURE FOR ACOUSTIC APPLICATIONS

S. M. DASH, N. SINHA, and D. C. KENZAKOWSKI (Science Applications International Corp., Propulsion Fluid Dynamics Div., Fort Washington, PA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 643-654. refs

Our ability to predict the structure of supersonic jets and their noise emission is critically dependent on our ability to properly model the turbulence. This is quite difficult for high-speed flows where density fluctuations are significant and turbulent compressibility-effects influence the jet mixing and shock structure. In earlier work, a hybrid two-equation turbulence model (keCC/kW) was shown to perform reasonably well over a wide range of conditions for axisymmetric jets. A new two-equation model has been formulated using compressible-dissipation concepts, which shows promise of greater generality. Preliminary applications of this model to high-speed shear layers indicate that it does reproduce the trends of the recent data. The extension from shear layers to jets is not straightforward and is being guided by building-block data. Author

A93-19204

COMBINED NOISE AND FLOW CONTROL OF SUPERSONIC JETS USING SWIRL

K. KNOWLES (Cranfield Inst. of Technology, Shrivenham, United Kingdom) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 746-751. refs

The study explores the practical possibility of reducing shock-associated noise and controlling mass flow in a supersonic jet. A brief review of the evidence for swirl as a noise reduction mechanism shows that the available experiment results are not particularly favorable, but are they not definitive either. The most promising experiments confirm that swirl can reduce supersonic jet noise, but the frequencies and directivities were not practically useful for reducing the EPNL of an SST at flyover. Some new

analytical results showing the possibilities of combined noise and mass flow control in supersonic jets are reported. It is found that nozzle performance does not need to be degraded by the introduction of swirl (specific thrust can be increased with swirl); the swirl velocity profile, however, needs to be carefully controlled. It is recommended that specific case studies be made so that swirl can be considered in concert with variable engine cycles.
P.D.

A93-19207 National Aeronautics and Space Administration. John F. Kennedy Space Center, Cocoa Beach, FL.
A REVIEW OF CRACK PROPAGATION UNDER UNSTEADY LOADING
H. H. BRYAN (NASA, Kennedy Space Center, Cocoa Beach, FL; Georgia Inst. of Technology, Atlanta) and K. K. AHUJA (Georgia Inst. of Technology, Atlanta) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 767-778. Research supported by NASA and Georgia Inst. of Technology refs

The theories and research current available on crack propagation under unsteady loadings, especially those of acoustic origin, are reviewed. Since the original theories on fatigue failure did not account for random loading conditions, modified theories which provide statistical methods for evaluating the random loading have emerged. The impact of acoustic fatigue in the aerospace industry, basic principles such as fatigue crack initiation and propagation and load interactions, and testing procedures are discussed. Attention is also given to metal and metal alloy structures, fiber-reinforced composites and nonmetallic structures, short crack growth, and the effects of temperature, moisture, and corrosion on structures. Suggestions for future research in this field are presented, namely, studies on the effect of 'snap-through' response and associated crack growth patterns, studies in microcrack and 'small crack'; propagation under unsteady loading conditions, and the development of an accurate analytical model to predict acceleration and retardation effects in fatigue crack growth under random loading conditions. P.D.

A93-19208
SONIC FATIGUE ANALYSIS OF AN AIRCRAFT WING FLAP BY THE MATRIX DIFFERENCE EQUATION METHOD
P. H. DENKE and C. YU (Douglas Aircraft Co., Long Beach, CA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 779-784. refs

The matrix difference equation (MDE) method, a new approach to finite element modeling of vibrating structures, is presented. The method features simplified data preparation, detailed modeling, low-computing cost, fast turn-around, and reliable results. A recent extension to sonic fatigue is described. The outboard wing flap of the C-17 military transport is subjected to direct jet impingement during take-off and landing. The program was extended as required, the revised program was tested, and numerous analytical studies were conducted over an eight-month period. The MDE method is found to have the potential of accounting for all of the structural and random acoustic variables that affect fatigue life. The spectral modal frequency response method offers a rational approach to computing the response of FEM models to random forcing functions, but the task of assembling the input data and performing the calculations appears to be excessive. P.D.

A93-19211
NONLINEAR RESPONSE AND SONIC FATIGUE OF HIGH SPEED AIRCRAFT
RIMAS VAICAITIS and P. KAVALLIERATOS (Columbia Univ., New York) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 800-808. refs

An analytical model for nonlinear response of composite panels to random surface pressures and aerodynamic heating is presented. The random surface pressures are simulated in the space-time domain and the governing nonlinear equations of motion are solved using a Galerkin-like modal method and a numerical time domain integration procedure. The required statistical quantities such as moments, probability density histograms, peak distribution histograms, and crossing rates are calculated directly from the response time history of displacement or stress. It is found that thermal heating induces buckling, and at some combinations of heating temperatures and input sound pressure levels a 'snap-through' type dynamic response is induced, resulting in large stress reversals. At high temperatures, a large nonlinear static response and small dynamic random vibrations are observed. For the anticipated severe thermal and noise environment of high-speed aircraft, the various simplified linear theories used to predict stress response and fatigue life of composite surface panels would not produce realistic structural configurations and reliable designs.
P.D.

A93-19217
FLOWFIELD MEASUREMENTS FOR A SUPERSONIC MIXER EJECTOR IN FORWARD FLIGHT
T. G. TILLMAN and W. PATRICK (United Technologies Research Center, East Hartford, CT) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 854-862. Research supported by U.S. Navy refs
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Results of an experimental study of a supersonic mixer ejector in forward flight are described. The mixing performance of a 2D supersonic mixer ejector in the presence of high-speed forward flight is described. The experiment was performed over the range of forward flight Mach numbers from 0.3 to 0.5, a primary total temperature of 1000 F, and a primary jet exit Mach number of 1.5. Detailed flowfield surveys of total temperature, total pressure, and static pressure were performed to characterize the mixing. LDV measurements of the mixer ejector exit plane 3D velocity field were performed in order to quantify the vortical flows responsible for enhanced mixing. The mixer ejector axial vorticity mixing benefit is found to exist for increased forward flight Mach numbers. Local regions of high axial velocity are identified at the mixer ejector exit plane. These regions could represent a significant jet noise source. P.D.

A93-19220
UNSTEADY PRESSURES UNDER IMPINGING JETS IN CROSSFLOWS
K. KNOWLES, D. BRAY, and M. J. WILSON (Cranfield Inst. of Technology, Shrivenham, United Kingdom) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 882-889. Research supported by British Aerospace (Military Aircraft), Ltd. and SERC refs

The flowfield surrounding single and twin jets impinging in a cross-flow has been investigated experimentally. Two regions of the flowfield are seen to be particularly unsteady: the ground vortex formed by separation of the wall jet in the cross-flow; and the fountain formed between two adjacent impinging jets. The ground vortex formed by twin (side-by-side) impingen jets is found to be even more unsteady than that due to a single jet. The unsteadiness has been quantified by ground plane pressure measurements. These have shown the fluctuations to be broadband in nature but with a low frequency hump. This confirms results from elsewhere using low speed jets. The present work also suggests that the peak amplitudes in ground plane pressure fluctuations occur either side of the vortex. There is, as yet, no evidence that the vortex fluctuations are fed by impinging jet instabilities. Nor does nozzle pressure ratio seem to have a direct effect on the spectrum of fluctuations. Author

A93-19250* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
PARTIALLY EXPOSED POLYMER DISPERSED LIQUID CRYSTALS FOR BOUNDARY LAYER INVESTIGATIONS
DEVENDRA S. PARMAR and JAG J. SINGH (NASA, Langley

Research Center, Hampton, VA) Applied Physics Letters (ISSN 0003-6951) vol. 61, no. 17 Oct. 26, 1992 p. 2039-2041. Research supported by Old Dominion Univ. refs
(Contract NAS1-18584)
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A new configuration termed partially exposed polymer dispersed liquid crystal in which the liquid crystal microdroplets dispersed in a rigid polymer matrix are partially entrapped on the free surface of the thin film deposited on a glass substrate is reported. Optical transmission characteristics of the partially exposed polymer dispersed liquid crystal thin film in response to an air flow induced shear stress field reveal its potential as a sensor for gas flow and boundary layer investigations. Author

A93-19280
A STUDY ON STABILITY AND RESPONSE ANALYSIS OF A NONLINEAR ROTOR SYSTEM WITH MASS UNBALANCE AND SIDE LOAD
TING N. SHIAU (National Cheng Kung Univ., Tainan, Taiwan), JON L. HWANG, and YUAN B. CHANG (Chung Shan Inst. of Science and Technology, Taichung, Taiwan) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-7)

The stability of steady state synchronous and nonsynchronous response of a nonlinear rotor system supported by squeeze-film dampers is investigated. The nonlinear differential equations which govern the motion of rotor bearing system are obtained by using the Generalized Polynomial Expansion Method. The steady state response of system is obtained by using the hybrid numerical method which combines the merits of the harmonic balance and collocation methods. The stability of system response is examined using Floquet-Liapunov theory. Using the theory, the performance may be evaluated with the calculation of derivatives of nonlinear hydrodynamic forces of the squeeze-film damper with respect to displacement and velocity of the journal center. In some cases, these derivatives can be expressed in closed form and the prediction of the dynamic characteristic of the nonlinear rotor system will be more effective. The stability results are compared to those using a direct numerical integration method and both are in good agreement. Author

A93-19287
DESIGN FEATURES OF THE GTD 8000 AND GTD 15000 MARINE GAS TURBINE ENGINES
VIKTOR I. ROMANOV (NPO Mashproekt, Nikolayev, Ukraine) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992
(ASME PAPER 92-GT-15)

An account is given of the design features and performance of the GTD 8000 and GTD 15000 marine gas turbines, whose simple-cycle thermodynamic efficiencyis of the order of 34-35 percent. A development history is presented for the component design improvements through which such performance levels were achieved. Attention is given to the counterflow combustor, bearings, and high pressure compressor/turbine spool rotor joint assembly features. These powerplants are suitable for hydrofoil and hovercraft applications. O.C.

A93-19290
EXPERIMENTAL AND THEORETICAL ANALYSIS OF THE FLOW IN A CENTRIFUGAL COMPRESSOR VOLUTE
E. AYDER, R. VAN DEN BRAEMBUSSCHE (Von Karman Inst. for Fluid Dynamics, Rhode-St.-Genese, Belgium), and J. J. BRASZ (Carrier Corp., Syracuse, NY) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-30)

Detailed measurements of the swirling flow in a centrifugal compressor volute with elliptical cross section are presented. They show important variations of the swirl- and through-flow velocity, total and static pressure distribution at the different volute cross sections and at the diffuser exit. The basic mechanisms defining the complex 3D flow structure are clarified. The different sources of pressure losses have been investigated and used to improve the prediction capability of one dimensional mean streamline analysis correlations. The tangential flow loss model, under decelerating flow conditions, and friction loss model are confirmed. New empirical loss coefficients are proposed for the exit cone loss model and the tangential flow loss model for the case of accelerating flow in the volute. Author

A93-19303
ELECTROMECHANICAL MEASUREMENT OF TURBOMACHINERY BLADE TIP-TO-CASING RUNNING CLEARANCE
A. G. SHEARD (Rotadata, Ltd., Derby, United Kingdom) and S. R. TURNER (Rolls-Royce, PLC, Bristol, United Kingdom) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-50)

The development of a second-generation tip clearance measurement system of much reduced size and weight is described. The concepts used in the original design were retained, but a more compact stepper motor drive unit and electronics model facilitated the reduction in size. The probe design was adapted to fit the reduced size actuator, but the same mechanism for spring loading onto a datum phase physically close to the measurement point was retained. Following the design of a second generation system, a four-stage commissioning exercise was undertaken. The first stage involved a series of laboratory tests to verify the system's performance. In all installations the second-generation system performed reliably and gave results which were in accordance with those obtained using the original system of Davidson et al. (1983). It is concluded that the second-generation system performance was comparable to that of the original system. C.A.B.

A93-19316
THE VORTEX BEHAVIOUR OF THE ROTATING-STALL CELL OF A CENTRIFUGAL COMPRESSOR WITH VANED DIFFUSER
Y. N. CHEN (Sulzer Brothers, Ltd., Winterthur, Switzerland), U. SEIDEL, U. HAUPT, and M. RAUTENBERG (Hannover, Univ., Hanover, Germany) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by DFG refs
(ASME PAPER 92-GT-66)

The rotating stall cell that is enveloped by the outer lobe of the Rossby wave and guided by the high-low vortex pair is experimentally investigated by means of two parallel transducers that were located on the opposing walls of a semivaneless annular space between the radial-blading impeller and the vaned diffuser. The flow field determined by these means corresponds to the flow around the entire circumference of the impeller outlet, and is composed of stalled and unstalled regions. Attention is given to the strength of the jetstream along the front of the Rossby waves corresponding to the high pressure ridge and the low pressure trough. O.C.

A93-19320
CALCULATION OF TURBULENT FLOW FOR AN ENCLOSED ROTATING CONE
N. E. MAY (Aircraft Research Association, Ltd., Bedford, United Kingdom), J. W. CHEW (Rolls-Royce, PLC., Derby, United Kingdom), and P. W. JAMES (Polytechnic South West, Plymouth, United Kingdom) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by SERC and Rolls-Royce, PLC refs
(ASME PAPER 92-GT-70)

Prediction of the flow in the cavity between a rotating cone and an outer stationary cone with and without throughflow is considered. A momentum-integral method and a finite difference method for solution of the Reynolds-averaged Navier-Stokes

equations with a mixing-length model of turbulence are applied. These two methods have previously been validated for flow between co-rotating and rotor-stator disk systems, but have not been properly tested for conical systems. Both methods have been evaluated by comparing predictions with the experimental measurements of other workers. There is good agreement for cone half angles greater than or equal to 60 deg but discrepancies are evident for smaller angles. 'Taylor-type' vortices, the existence of which has been postulated by other workers and which are not captured by the present steady, axisymmetric models, may contribute to these discrepancies. Author

A93-19325* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
HOT STREAKS AND PHANTOM COOLING IN A TURBINE ROTOR PASSAGE. I - SEPARATE EFFECTS
RICHARD J. ROBACK and ROBERT P. DRING (United Technologies Research Center, East Hartford, CT) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract F33615-88-C-2829; NAS8-36801)
(ASME PAPER 92-GT-75)

Experimental documentation and analytical correlations demonstrating the effects of hot streak accumulation and phantom cooling on turbine rotor airfoil surface temperature. Test results are shown for a range of controlling variables to identify where streak accumulation and phantom cooling are most likely to be strongest. These variables include streak injection location, streak-to-free stream density ratio and coolant-to-free stream density and velocity ratios. R.E.P.

A93-19326* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
HOT STREAKS AND PHANTOM COOLING IN A TURBINE ROTOR PASSAGE. II - COMBINED EFFECTS AND ANALYTICAL MODELLING
RICHARD J. ROBACK and ROBERT P. DRING (United Technologies Research Center, East Hartford, CT) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract F33615-88-C-2829; NAS8-36801)
(ASME PAPER 92-GT-76)

Experimental documentation and analytical correlations demonstrating the effects of hot streak accumulation and phantom cooling on turbine rotor airfoil surface temperature are presented. Results are shown which quantify the impact of a nonuniform temperature profile at the entrance of a turbine due to combustor-generated hot and cold streaks, and cooling air discharged from the trailing edge of the upstream stator. Experimental results are shown for a range of controlling variables to identify where streak accumulation and phantom cooling were most likely to be strongest. These variables include streak-to-free stream density ratio, streak injection location, and coolant-to-free stream density and velocity ratios. Experimental results are shown for the combined effects of hot streak and stator coolant on the adiabatic recovery temperature of the rotor. C.A.B.

A93-19327
EXTENDING THE FATIGUE LIFE OF AIRCRAFT ENGINE COMPONENTS BY HOLE COLD EXPANSION TECHNOLOGY
ANTONIO C. RUFIN (Fatigue Technology, Inc., Seattle, WA) Jun. 1992 9 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by U.S. Navy refs
(ASME PAPER 92-GT-77)

The split-sleeve cold expansion process has been used successfully for over 20 years to extend the fatigue life of holes in aircraft structures. Cold expansion technology can also be applied to enhance engine low-cycle fatigue (LCF) performance in both production and repair applications. Specific test data are presented showing that fatigue life extension can be attained by cold expansion of holes in a wide range of situations (including non-round hole geometries and low edge margins), and in components subjected to high operating temperatures. A cold expanded bushing system is compared to standard shrink-fit bushing installations. Finally, two case studies are used to illustrate the application of cold expansion to full-scale engine components. Author

A93-19344
STUDIES OF JET THERMAL STABILITY IN A FLOWING SYSTEM
S. P. HENEGHAN, C. R. MARTEL, T. F. WILLIAMS, and D. R. BALLAL (Dayton Univ., OH) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract F33615-87-C-2767)
(ASME PAPER 92-GT-106)

A 'Phoenix rig' single-pass flowing heat-exchanger facility has been devised to test the carbon deposition tendencies of jet fuels in their circulation systems. Three samples each of baseline JP fuels and JP fuels blended with additives have been thus tested, and the results obtained vindicate the usefulness of the Phoenix rig. The blended fuel tests indicated significant improvement in fuel thermal stability; block temperature and test duration increased the total carbon deposits in a nonlinear manner. O.C.

A93-19352
ENGINE TESTING OF A PROTOTYPE LOW NO(X) GAS TURBINE COMBUSTOR
KENNETH O. SMITH (Solar Turbines, Inc., San Diego, CA) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-116)

The design of a lean-premixed, annular, dry low NO(x) combustor for a 5500 hp Centaur Type H gas turbine is discussed. Results from early engine tests of prototype combustion hardware are presented. The emissions results with natural gas fueling meet the development goals of less than 25 ppm NO(x) (at 15 percent O2) and 50 ppm CO. Several techniques to extend the low emissions operating range of the lean-premixed system are shown to be effective. Author

A93-19369
EXPERIMENTAL AND THEORETICAL INVESTIGATION OF A RESEARCH ATOMIZER/COMBUSTION CHAMBER CONFIGURATION
C. HASSA, E. BLUEMCKE, M. BRANDT, and H. EICKOFF (DLR, Inst. fuer Antriebstechnik, Cologne, Germany) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-137)

A mathematical model of two-phase flows in gas turbine combustors is presently validated in light of an experimental airblast atomizer/combustion chamber configuration. Inlet boundary conditions were measured within the nozzle by laser two-focus velocimetry, and the starting velocities and mass fluxes for the spray's droplet sizes were determined by phase-Doppler anemometry. The spray exhibits the structure of an axial acceleration of all drop sizes, as well as a subsequent dispersion of the droplets and radial separation by centrifugal force according to size. O.C.

A93-19371
ACHIEVING MANUFACTURING EXCELLENCE FOR GAS TURBINE COMPONENTS THROUGH FOCUSED IMPLEMENTATION OF TECHNOLOGY
CHESTER HAYNER (Pratt & Whitney Group, Manufacturing Engineering and Support Services, Southington, CT) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992
(ASME PAPER 92-GT-139)

This paper explains how focused implementation of a broad range of technologies was used as the key strategy resulting in the establishment of highly efficient, dedicated facility for

manufacture of gas turbine disk, hub, and drum rotor components. The physical and operational constraints associated with the conversion of an existing operating facility, along with the rigid time constraints, required a carefully phased and integrated plan. Reviews and tradeoffs of each of the many available manufacturing technologies are discussed and those selected, such as flowline units, group technology, rule based design/manufacturing and product improvement teams are explained in the context of their implementation phase-in. Before and after performance results are provided and ongoing enhancements of this manufacturing system are covered. Author

A93-19373
LOW LEAKAGE FIBER METAL SEALS
G. P. JARRABET and L. LU (Technetics Corp., DeLand, FL) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992
(ASME PAPER 92-GT-141)
A ceramic foam-compositing process has been developed for incorporating a closed-cell foam into a fiber netal structure; the composite sealing material thus obtained meets the low leakage requirement of advanced gas turbine engines. The seals' abradability, erosion resistance, and low weight are maintained, and the seals are produced by brazing preformed rub strips to backing rings, followed by final machining. O.C.

A93-19379
UNSTEADY PRESSURE MEASUREMENTS IN A ROTATING CENTRIFUGAL IMPELLER
G. ROTH (Stuttgart Univ., Germany) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-152)
The design of a shrouded radial test impeller which enables the application of miniature pressure transducers inside the blades is presented. An explanation of the measurement- and analysis technique is given. The results of suction side blade surface pressure measurements at several points of a performance line are presented. Two different types of diffuser rotating stall were detected. The pressure behavior at impeller stall and surge inception is demonstrated. Furthermore, the periodic engine order blade surface pressure signals at a stable operating point are shown. Author

A93-19386
TURBINE BLADE VIBRATION MONITORING SYSTEM
T. KAWASHIMA, H. IINUMA, T. WAKATSUKI, and N. MINAGAWA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-159)
An optical blade vibration monitoring system applicable to high-pressure turbine blading of gas turbines is described. The system uses high-intensity He-Ne lasers, optical fibers, and associated electronics, and can monitor rotor blade vibration under engine running conditions. The system is applied to actual gas turbine engines, and its effectiveness as a useful tool for gas turbine blade vibration evaluation is demonstrated. P.D.

A93-19387
RIM SEAL EXPERIMENTS AND ANALYSIS OF A ROTOR-STATOR SYSTEM WITH NONAXISYMMETRIC MAIN FLOW
K. HAMABE and K. ISHIDA (Kawasaki Heavy Industries, Ltd., Akashi, Japan) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-160)
To examine the simplified model to predict the ingress flow rate which was formerly proposed by the authors, the sealing characteristics of a shrouded rotor-stator system with a nonaxisymmetric main flow is studied using gas concentration measurements in the wheel-space. The predicted value for the sealing effectiveness as well as the minimum cooling air flow ratio necessary to prevent ingress is shown to be relatively in good agreement with the test results. It is also found that for the precise prediction of the sealing effectiveness, the circumferential static pressure distribution in the annulus is needed. Author

A93-19405
BEHAVIORS OF THE LATERALLY INJECTED JET IN FILM COOLING - MEASUREMENTS OF SURFACE TEMPERATURE AND VELOCITY/TEMPERATURE FIELD WITHIN THE JET
SHINJI HONAMI, TAKAAKI SHIZAWA (Tokyo Science Univ., Japan), and ATSUSHI UCHIYAMA (Mitsubishi Heavy Industries, Ltd., Takasago, Japan) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-180)
This paper presents the behaviors of the injected jet on the flat surface in lateral injection of the film-cooling. Simultaneous velocity and temperature measurements were made by the double-wire probe. The test surface was also covered with an encapsulated temperature-sensitive liquid crystal. The image processing system based on the temperature and hue of the liquid crystal calibration provides the surface temperature distributions. The tests were conducted at three kinds of mass flux ratio of 0.5, 0.85, and 1.2. The laterally injected jet has an asymmetric structure with a large scale of vortex motion in one side caused by the interaction with the primary stream. Asymmetry is promoted with mass flux ratio increased, resulting in low film-cooling effectiveness. Author

A93-19412
HEAT TRANSFER AND TURBULENCE IN A TURBULATED BLADE COOLING CIRCUIT
N. ABUAF (General Electric Co., Schenectady, NY) and D. M. KERCHER (GE Aircraft Engines, Lynn, MA) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-187)
The aero-thermal performance of a typical turbine blade three-pass turbulated cooling circuit geometry was investigated in a 10X plexiglas test model. The model closely duplicated the blade's leading edge, midchord and trailing edge cooling passage geometries. Steady state heat transfer coefficient distributions along the blade pressure side wall (convex surface) of the cooling circuit passages were measured with a thin-foil heater and a liquid crystal temperature sensor assembly. The heat transfer experiments were conducted on rib-roughened channels with staggered turbulators along the convex and concave surfaces of the cooling passages. Mid-channel axial velocity and turbulence intensity measurements were taken by hot wire anemometry at each passage end of the three-pass cooling circuit to characterize and relate the local thermal performance to the turbulence intensity levels. The near-atmospheric experimental data are compared with results of a Computational Fluid Dynamics (CFD) analysis at the operating internal environment for a 1X rotating model of the blade cooling circuit and other turbulator channel geometry heat transfer data investigations. The comparison between the measurements and analysis is encouraging. Differences with other heat transfer data appear reasonably understood and explainable. Author

A93-19413
INFLUENCE OF SURFACE HEATING CONDITION ON LOCAL HEAT TRANSFER IN A ROTATING SQUARE CHANNEL WITH SMOOTH WALLS AND RADIAL OUTWARD FLOW
J. C. HAN, Y. M. ZHANG (Texas A & M Univ., College Station), and C. P. LEE (General Electric Co., Cincinnati, OH) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by General Electric Co refs
(ASME PAPER 92-GT-188)
The study investigates the effect of the surface heating condition

on the local heat transfer coefficient in a rotating square channel with smooth walls and radial outward flow for Reynolds numbers from 2500 and 25,000 and rotation numbers from 0 to 0.352. Four surface heating conditions were tested: (1) four walls uniform temperature, (2) temperature ratio of leading surface to side wall and trailing surface to side wall is 1.05 and 1.10, respectively, (3) trailing surface hot and remaining three walls cold, and (4) leading surface hot and remaining three walls cold. It is shown that the heat transfer coefficients on the leading surface are much lower than that of the trailing surface due to rotation. It is suggested that the local wall heating condition creates the local buoyancy forces which reduce the effects of the bulk buoyancy and Coriolis forces. Therefore, the local heat transfer coefficients on the leading and trailing surfaces are altered by the surface local heating condition. C.A.B.

A93-19415

HEAT TRANSFER IN SERPENTINE FLOW PASSAGES WITH ROTATION

S. MOCHIZUKI, J. TAKAMURA (Tokyo Univ. of Agriculture and Technology, Koganei, Japan), S. YAMAWAKI (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan), and WEN-JEI YANG (Michigan Univ., Ann Arbor) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-190)

Results are reported of an experimental study tracing heat transfer performance in a rotating serpentine flow passage of a square cross section. The test section is preceded by a hydrodynamic calming region. The test model is a blow-up (by seven times) of actual winding flow passages in rotor blades. It is concluded that the flow in the 180-deg bends exhibits strong 3D structure. The heat transfer coefficient in the bend is substantially higher than in the straight flow passages. The average heat transfer characteristics over the entire flow passage is greatly affected by flow at the 180-deg bends. Due to secondary flow induced by the Coriolis force, the heat transfer coefficient in the radially outward flow passages diminish on the leading surface, but increase on the trailing surface, with an increase in rotational speed. The trend is reversed in the radially inward flow passages. C.A.B.

A93-19416 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

HEAT TRANSFER IN ROTATING SERPENTINE PASSAGES WITH TRIPS SKEWED TO THE FLOW

B. V. JOHNSON, J. H. WAGNER (United Technologies Research Center, East Hartford, CT), G. D. STEUBER (Pratt & Whitney Group, East Hartford, CT), and F. C. YEH (NASA, Lewis Research Center, Cleveland, OH) Jun. 1992 11 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Previously announced in STAR as N92-20235 Research supported by United Technologies Corp. refs
(Contract NAS3-23691; RTOP 505-62-52)
(ASME PAPER 92-GT-191)

Experiments were conducted to determine the effects of buoyancy and Coriolis forces on heat transfer in turbine blade internal coolant passages. The experiments were conducted with a large scale, multi-pass heat transfer model with both radially inward and outward flow. An analysis of the governing flow equations showed that four parameters influence the heat transfer in rotating passages: coolant-to-wall temperature, rotation number, Reynolds number, and radius-to-passage hydraulic diameter ratio. Results were correlated and compared to previous results from similar stationary and rotating models with smooth walls and with trip strips normal to the flow direction. It was concluded that (1) both Coriolis and buoyancy must be considered in turbine blade cooling designs with trip strips, (2) the effects of rotation are markedly different depending upon the flow direction, and (3) the heat transfer with skewed trip strips is less sensitive to buoyancy than the heat transfer models with either smooth or normal trips. Therefore, skewed trip strips rather than normal trip strips are recommended and geometry-specific tests are required for accurate design. Author

A93-19417

DISCHARGE COEFFICIENTS OF HOLES ANGLED TO THE FLOW DIRECTION

N. HAY, S. E. HENSHALL, and A. MANNING (Nottingham Univ., United Kingdom) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-192)

In the cooling passages of gas turbine blades, branches are often angled to the direction of the internal flow. This is particularly the case with film cooling holes. Accurate knowledge of the discharge coefficient of such holes at the design stage is vital so that the holes are correctly sized thus avoiding wastage of coolant and the formation of hot spots on the blade. This paper describes an experimental investigation to determine the discharge coefficient of 30 deg inclined holes with various degrees of inlet radiusing and with the axis of the hole at various orientation angles to the direction of the flow. Results are given for nominal main flow Mach numbers of 0, 0.15 and 0.3. The effects of radiusing, orientation and cross flow Mach number are quantified in the paper, the general trends are described, and the criteria for optimum performance are identified. Author

A93-19420* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.

AN EXPERIMENTAL STUDY OF HEAT TRANSFER IN A LARGE-SCALE TURBINE ROTOR PASSAGE

MICHAEL F. BLAIR (United Technologies Research Center, East Hartford, CT) Jun. 1992 15 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract NAS8-37351; NAS8-38870)
(ASME PAPER 92-GT-195)

An experimental study of the heat transfer distribution in a turbine rotor passage was conducted in a large-scale, ambient temperature, rotating turbine model. Heat transfer was measured for both the full-span suction and pressure surfaces of the airfoil as well as for the hub endwall surface. The objective of this program was to document the effects of flow three-dimensionality on the heat transfer in a rotating blade row (vs a stationary cascade). Of particular interest were the effects of the hub and tip secondary flows, tip leakage and the leading-edge horseshoe vortex system. The effect of surface roughness on the passage heat transfer was also investigated. Midspan results are compared with both smooth-wall and rough-wall finite-difference two-dimensional heat transfer predictions. Contour maps of Stanton number for both the rotor airfoil and endwall surfaces revealed numerous regions of high heat transfer produced by the three-dimensional flows within the rotor passage. Of particular importance are regions of local enhancement (as much as 100 percent over midspan values) produced on the airfoil suction surface by the secondary flows and tip-leakage vortices and on the hub endwall by the leading-edge horseshoe vortex system. Author

A93-19425

TIP CLEARANCE EFFECT ON HEAT TRANSFER AND LEAKAGE FLOWS ON THE SHROUD-WALL SURFACE IN AN AXIAL FLOW TURBINE

MASAYA KUMADA, SATOSHI IWATA (Gifu Univ., Japan), MASAKAZU OBATA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan), and OSAMU WATANABE (Toyo Denki Co., Ltd., Kasugai, Japan) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract MOESC-01550171)
(ASME PAPER 92-GT-200)

An axial flow turbine for a turbocharger is used as a test turbine, and the local heat transfer coefficient on the surface of the shroud is measured under uniform heat flux conditions. The nature of the

tip clearance flow on the shroud surface and a flow pattern in the downstream region of the rotor blades are studied, and measurements are obtained by using a hot-wire anemometer in combination with a periodic multisampling and an ensemble averaging technique. Data are obtained under on- and off-design conditions. The effects of inlet flow angle, rotational speed and tip clearance on the local heat transfer coefficient are elucidated. The mean heat transfer coefficient is correlated with the tip clearance, and the mean velocity is calculated by the velocity triangle method for approximation. A leakage flow region exists in the downstream direction beyond the middle of the wall surface opposite the rotor blade, and a leakage vortex is recognized at the suction side near the trailing edge. Author

A93-19431
SCALING OF THE TWO-PHASE FLOW DOWNSTREAM OF A GAS TURBINE COMBUSTOR SWIRL CUP - MEAN QUANTITIES
H. Y. WANG, V. G. MCDONELL, W. A. SOWA, and G. S. SAMUELSEN (California Univ., Irvine) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by GE Aircraft Engines refs
(ASME PAPER 92-GT-207)
A production gas turbine combustor swirl cup and a 3x-scale model, both featuring co-axial, counter-swirling air streams are characterized at atmospheric pressure and in the absence of reaction. Spatially-resolved measurements of continuous phase (gas in the presence of spray) and droplet size and velocity are acquired downstream of the production and 3x-scale swirl cups by using two-component phase Doppler interferometry. The effect of scale on the behavior of the continuous phase and droplets is investigated by comparing the continuous phase velocity and droplet size and velocity at geometrically analogous positions. The continuous phase flow field scales well at the exit of the swirl cup. Farther downstream, differences occur which are due to disparity in entrainment. The droplet velocities scale reasonably well, but the sizes show some differences. However, the difference in size is less significant than it is between the two atomizers in the absence of the swirl cup assemblies. Author

A93-19440
INVESTIGATIONS ON A RADIAL COMPRESSOR TANDEM-ROTOR STAGE WITH ADJUSTABLE GEOMETRY
B. JOSUHN-KADNER (Bochum, Ruhr-Univ., Germany) and B. HOFFMANN (DLR, Inst. fuer Antriebstechnik, Cologne, Germany) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by MTU Motoren- und Turbinen-Union Muechen GmbH refs
(ASME PAPER 92-GT-218)
A radial compressor stage has been investigated experimentally for aerodynamic stage optimization. The rotor consists of a profiled axial inducer and a conventionally designed radial impeller. Inducer and impeller can be locked at different circumferential positions relative to each other thus, forming a tandem wheel with adjustable geometry. Conventional and laser-2-focus system measurements for the tandem-rotor and the stage were performed at different operating points to study the influence of the circumferential clearance geometry between inducer and impeller with respect to compressor characteristics and performance. Furthermore, 3D Navier-Stokes calculations are being developed at design point condition to analyze the flow field. Small influence of the inducer adjustment on the rotor characteristics is observed. The maximum rotor efficiency of 93.5 percent varies in a range of less than 1 percent depending on the different inducer positions. Author

A93-19442
THE OPTIMUM VALUE OF THE NOZZLE OUTLET ANGLE OF TURBINE STAGES
KRZYSZTOF KOSOWSKI (Gdansk Technical Univ., Poland) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-224)
The paper presents the results of theoretical research on the influence of the main design parameters on the optimum value of the nozzle outlet angle. The analysis was carried out for the stages with the disk and the drum rotors. The cascade losses were determined using Traupel's and Bammert's generalized cascade data. The calculations have proved that the blade height, the profile chord and the number of stages in the group are the most important factors influencing the optimum nozzle outlet angle. Author

A93-19444
FLUTTER OF GROUPED TURBINE BLADES
D. S. WHITEHEAD and D. H. EVANS (Westinghouse Electric Corp., Orlando, FL) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-227)
An analysis is presented to predict flutter in a wheel of turbine blades which are connected together into a number of identical groups. The natural frequencies and mode shapes of a group are assumed to be known. The unsteady aerodynamic coefficients for free-standing blades are assumed to be known from an unsteady aerodynamic program, and FINSUP is used here. The work fed into the vibration by the aerodynamic forces is then calculated. This is illustrated by two examples of low pressure steam turbine blade rows GR-1 and GR-2. On GR-1 the three modes considered are all found to be stable, but on GR-2 the lowest frequency mode shows some instability. Typing the blades together in groups is found to be stabilizing. Blade response, measured by a Blade Vibration Monitor at two different installations, is shown for a range of operating conditions. The measured responses indicate the GR-1 blade is stable whereas the GR-2 blade shows, at the lowest frequency, high response that is dependent on turbine operating conditions. Author

A93-19446
FLEXIBLE MANUFACTURING OF AIRCRAFT ENGINE PARTS
OSSAMA M. HASSAN and DOUGLAS M. JENKINS (GE Aircraft Engines, Lynn, MA) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-229)
GE Aircraft Engines, a major supplier of jet engines for commercial and military aircraft, has developed a fully integrated manufacturing facility to produce aircraft engine components in flexible manufacturing cells. This paper discusses many aspects of the implementation including process technologies, material handling, software control system architecture, socio-technical systems and lessons learned. Emphasis is placed on the appropriate use of automation in a flexible manufacturing system. Author

A93-19450
INTERNAL COOLING PASSAGE HEAT TRANSFER NEAR THE ENTRANCE TO A FILM COOLING HOLE - EXPERIMENTAL AND COMPUTATIONAL RESULTS
A. R. BYERLEY (U.S. Air Force Academy, Colorado Springs, CO), T. V. JONES, and P. T. IRELAND (Oxford Univ., England) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Rolls-Royce, PLC refs
(ASME PAPER 92-GT-241)
Detailed heat transfer measurements were made near the entrance to a single film cooling hole using a transient liquid crystal technique in a large scale (100X) model. The hole inclination angle and flow extraction rate were varied across a range representative of actual engine conditions. Local values of heat transfer were found to exceed 6 times the levels associated with fully developed, turbulent channel flow. The region of maximum heat transfer enhancement occurred downstream of the hole entrance.

Computational and experimental flow diagnostics were performed to investigate the mechanisms responsible for the observed heat transfer distributions. The removal of the upstream boundary layer and the downwash created by a vortex pair were found to be important phenomena. Author

A93-19453
MEASUREMENTS OF THE EFFECT OF FREE-STREAM TURBULENCE LENGTH SCALE ON HEAT TRANSFER
R. W. MOSS and M. L. G. OLDFIELD (Oxford Univ., United Kingdom) Jun. 1992 8 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Rolls-Royce, PLC and Royal Aerospace Establishment refs
(ASME PAPER 92-GT-244)

The effects of free-stream turbulence scale on heat transfer through a turbulent flat plate boundary layer have been measured. A variety of turbulence spectra were produced by parallel bar grids. The design of these was guided by previous measurements of combustion chamber turbulence. Heat transfer was measured transiently using thin film gauges. The heat transfer to the plate was found to be a function of turbulence integral length scale as well as intensity, and is of relevance to gas turbine heat transfer where airfoils are subject to high turbulence levels from the combustor. Enhancement factors of up to 40 percent were experienced and the results extend conclusions drawn by other workers to higher turbulence levels and scales. Author

A93-19457
AN EXPERIMENTAL INVESTIGATION OF CONVECTIVE HEAT TRANSFER AT THE LEADING EDGE OF A GAS TURBINE AIRFOIL
S. GENDRON, N. J. MARCHAND, C. KORN (Ecole Polytechnique, Montreal, Canada), J. P. IMMARIGEON, and J. J. KACPRZYNSKI (National Research Council of Canada, Inst. for Aerospace Research, Ottawa) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(Contract DND-FA-220788)
(ASME PAPER 92-GT-248)

This paper describes the experimental methods used to determine the surface temperatures and heat-transfer coefficients at the leading edge, and elsewhere over the surface, of a specially designed double-edge wedge shell specimen subjected to cyclic heating in a high velocity hot gas stream generated by a burner rig. The methods included temperature measurements with thermocouples (embedded below the surface) as well as surface temperature measurements by optical pyrometry. The experiments were carried out at gas temperatures between 806 to 1323 C and velocities in the range from Mach 0.32 to Mach 0.39. The calibration procedures for each method, the various testing conditions to which the airfoil-like specimen was exposed and the results pertaining to the determination of the surface temperatures and heat-transfer coefficients are described and discussed. Author

A93-19466
DEVELOPMENT AND INDUSTRIAL APPLICATION OF THE 'ALL-OVER-CONTROLLED VORTEX DISTRIBUTION METHOD' FOR DESIGNING RADIAL AND MIXED FLOW IMPELLERS
S. J. WANG, M. J. YUAN, G. XI, S. X. LIU, D. T. QI, and X. J. CHAI (Xian Jiaotong Univ., China) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-262)

A detailed experimental exploration is conducted for the 3D impeller-model stages and multistage compressors designed by the 'all-over-controlled' vortex-distribution method for centrifugal and mixed-flow compressors. Excellent performance is obtained. Since the blade generation is conducted simultaneously with the mean s(2) flow surface analysis, the design time for an impeller is fully controllable, ensuring the possibility of enlarging these 3D impellers' range of application. The original method is presently improved in order to allow the design of small axial-length impellers. O.C.

A93-19494* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
BRUSH SEAL LEAKAGE PERFORMANCE WITH GASEOUS WORKING FLUIDS AT STATIC AND LOW ROTOR SPEED CONDITIONS
JULIE A. CARLILE, ROBERT C. HENDRICKS, and DENNIS A. YODER (NASA, Lewis Research Center, Cleveland, OH) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Previously announced in STAR as N92-16265 refs
(ASME PAPER 92-GT-304)

The leakage performance of a brush seal with gaseous working fluids at static and low rotor speed conditions was studied. The leakage results included for air, helium, and carbon dioxide at several bristle/rotor interferences. Also, the effects of packing a lubricant into the bristles and also of reversing the pressure drop across the seal were studied. Results were compared to that of an annular seal at similar operating conditions. In order to generalize the results, they were correlated using corresponding state theory. The brush seal tested had a bore diameter of 3.792 cm (1.4930 in.), a fence height of 0.0635 cm (0.025 in.), and 1800 bristles/cm circumference (4500 bristles/in. circumference). Various bristle/rotor radial interferences were achieved by using a tapered rotor. The brush seal reduced the leakage in comparison to the annular seal, up to 9.5 times. Reversing the pressure drop across the brush seal produced leakage rates approximately the same as that of the annular seal. Addition of a lubricant reduced the leakage by 2.5 times. The air and carbon dioxide data were successfully correlated using corresponding state theory. However, the helium data followed a different curve than the air and carbon dioxide data. Author

A93-19497
OPTIMUM DESIGN OF ROTOR-BEARING SYSTEMS WITH EIGENVALUE CONSTRAINTS
TING-YU CHEN (National Chung Hsing Univ., Taichung, Taiwan) and BO P. WANG (Texas Univ., Arlington) Jun. 1992 6 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-307)

The analysis and design of rotor-bearing systems with gyroscopic effects are discussed in this paper. The original problem of this nonproportionally damped mechanism is transformed into the state space form so that the transformed problem is similar to the eigenvalue problem for an undamped system. It can be easily solved by widely available eigensolvers and the eigenvalue sensitivities needed for the design optimization can also be obtained conveniently using the transformed form. The sequential linear programming technique is employed to solve the design optimization problem. The easy implementation of this proposed approach with a general purpose finite element program is shown in the solution algorithm. Author

A93-19506
DIRECT MEASUREMENTS OF SKIN FRICTION IN SUPERSONIC COMBUSTION FLOW FIELDS
K. M. CHADWICK, D. J. DETURRIS, and J. A. SCHETZ (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-320)

An experimental investigation was conducted to measure skin friction along the chamber walls of supersonic combustors. A direct force measurement device was used to simultaneously measure an axial and transverse component of the small tangential shear force passing over a nonintrusive floating element. This measurement was made possible with a sensitive piezoresistive deflection sensing unit. The floating head is mounted to a stiff cantilever beam arrangement with deflection due to the flow on the order of 0.00254 mm. This allowed the instrument to be a

nonnulling type. A second gauge was designed with active cooling of the floating sensor head to eliminate non-uniform temperature effects between the sensor head and the surrounding wall. A symmetric fluid flow was developed inside the quartz tube to provide cooling to the backside of the floating head. Tests showed that this flow did not influence the tangential force measurement. Author

A93-19535
THE EFFECTS OF INCIDENT TURBULENCE AND MOVING WAKES ON LAMINAR HEAT TRANSFER IN GAS TURBINES
K. DULLENKOPF and R. E. MAYLE (Karlsruhe Univ., Germany) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-377)
The effect of free-stream turbulence and moving wakes on augmenting heat transfer in accelerating laminar boundary layers is considered. First, the effect of free-stream turbulence is re-examined in terms of the Nusselt number and turbulence parameter which correctly account for the free-stream acceleration and a correlation for both cylinders in cross flow and airfoils with regions of constant acceleration is obtained. This correlation is then used in a simple quasi-steady model to predict the effect of periodically passing wakes on airfoil laminar heat transfer. A comparison of the predictions with measurements shows good agreement. Author

A93-19536
ROTOR CAVITY FLOW AND HEAT TRANSFER WITH INLET SWIRL AND RADIAL OUTFLOW OF COOLING AIR
F. W. STAUB (General Electric Co., Schenectady, NY) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by GE Aircraft Engines refs
(ASME PAPER 92-GT-378)
To enhance the reliability of turbine disk life prediction, experimental verification is necessary for analytical tools which calculate the heat transfer and flow field coefficients in turbine-stator cavities. A full-scale model of the forward cavity of a typical aircraft gas turbine is utilized employing a high-molecular-weight gas (Refrigerant-12) at ambient temperature and pressure conditions to match the dimensionless parameters at engine conditions. A first-order comparison is given of the velocity distribution and disk heat transfer coefficients calculated by the measured values and a CFD code. R.E.P.

A93-19537
EFFECTIVE SEALING OF A DISK CAVITY USING A DOUBLE-TOOTHED RIM SEAL
S. H. BHAVNANI, V. I. KHILNANI, L.-C. TSAI, J. M. KHODADADI, J. S. GOODLING (Auburn Univ., AL), and J. WAGGOTT (Dresser-Rand Corp., Steam Turbine, Motor and Generator Div., Wellsville, NY) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Dresser-Rand Corp., Alabama Electric Co-operative, and EPRI refs
(ASME PAPER 92-GT-379)
The sealing characteristics of an advanced air-cooled turbo-expander disk cavity are examined employing laser sheet flow visualization and static pressure measurements. Tests are conducted on a simplified half-scale model of an actual low pressure turbo-expander first-stage disk cavity. The superior performance of the seal studied is confirmed by comparison with a single-toothed rim seal and a simple axial rim seal. R.E.P.

A93-19539
AN EXTERNALLY PRESSURIZED AIR BEARING SYSTEM, JOURNALS AND THRUST, FOR APPLICATION TO SMALL TURBOMACHINERY
A. B. TURNER, S. J. DAVIES, Y. L. NIMIR, and J. D. RICHARDSON (Sussex Univ., Brighton, United Kingdom) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 Research supported by Aisin Seiki Co., Ltd. and Rolls-Royce, PLC refs
(ASME PAPER 92-GT-382)
Experiments have been conducted to examine the feasibility of externally pressurized air bearings for possible utilization in small high-speed turbomachinery such as compressor and turbine test rigs. The bearing was designed employing a simplified theory that proved to be adequate, with the problem of thermal expansion solved using brass bearings sleeved with graphited bronze, up to a shaft/bearing temperature of 180 C. A new thrust bearing was demonstrated with a potential capacity greatly in excess of the conventional aerostatic, close contact, parallel disk type of thrust bearing. R.E.P.

A93-19571
OPTIMAL CIRCUMFERENTIAL PLACEMENT OF CYLINDRICAL THERMOCOUPLE PROBES FOR REDUCTION OF EXCITATION FORCES
EBEN C. COBB, TSU-CHIEN CHEU, and JAY HOFFMAN (Textron Lycoming, Stratford, CT) Jun. 1992 10 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs
(ASME PAPER 92-GT-423)
This paper presents a design methodology to determine the optimal circumferential placement of cylindrical probes upstream of a turbine stage for reduced excitation forces. The potential flow forcing function generated by the probes is characterized by means of a Fourier analysis. A finite difference formulation is used to evaluate the sensitivity of the forcing function to the probe positions. An optimization scheme, based on the linear programming method, uses the sensitivity analysis results to reposition the probes such that the Fourier amplitudes of critical excitation orders are reduced. The results for an example design situation are presented. Author

A93-19582
REVIEW OF PROGRESS IN QUANTITATIVE NONDESTRUCTIVE EVALUATION. VOL. 11B; PROCEEDINGS OF THE 18TH ANNUAL REVIEW, BRUNSWICK, ME, JULY 28-AUG. 2, 1991 VOL. 11B
DONALD O. THOMPSON, ED. (DOE, Ames Laboratory; Iowa State Univ. of Science and Technology, Ames) and DALE E. CHIMENTI, ED. (Johns Hopkins Univ., Baltimore, MD) New York Plenum Press 1992 1146 p.
(ISBN 0-306-44206-X) Copyright
The present volume on progress in quantitative nondestructive evaluation discusses the application of guided acoustic waves to delamination deduction, an ultrasonic evaluation of environmentally degraded adhesive joints, an assessment of aircraft structural integrity by the detection of disbonds through ultrasonic scanning, and an ultrasonic scanning technique for the quantitative determination of the cohesive properties of adhesive joints. Attention is given to the detection of a weak adhesive/adherend interface in bonded joints by ultrasonic reflection measurements, an LF ultrasonic-spectroscopy technique for NDE of adhesive joints, a quantitative nondestructive evaluation of adhesive lap joints in a sheet molding compound by adaptation of a commercial bond tester, and an ultrasonic testing technique or measurement of the Poisson's ratio of thin adhesive layers. Topics addressed include physically based feature mapping concepts in bond interface evaluation and the examination of adhesive bonds using optically generated periodic surface acoustic waves. (For individual items see A93-19583 to A93-19699) P.D.

A93-19587* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ASSESSMENT OF AIRCRAFT STRUCTURAL INTEGRITY BY DETECTING DISBONDS THROUGH ULTRASONIC SCANNING
M. N. ABEDIN, D. R. PRABHU (Analytical Services and Materials, Inc.; NASA, Langley Research Center, Hampton, VA), and W. P. WINFREE (NASA, Langley Research Center, Hampton, VA) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11B; *Proceedings of the 18th Annual Review, Brunswick, ME, July*

28-Aug. 2, 1991 New York Plenum Press 1992 p. 1237-1244. refs
(Contract NAS1-19236; NAS1-18599)
Copyright

A study of nondestructive evaluation of aircraft bonded joints using the contact scanning technique is presented. Reflected signals acquired through the contacting transducer characterize the test region as being bonded or disbonded. Ultrasonic signals are attenuated more rapidly in the bonded regions when compared to disbonded regions. A peak amplitude based method and an artificial neural network are used to classify the signals. Results obtained using an artificial neural network exhibited significant insensitivity to signal variation when compared to the peak amplitude. Very good agreement is observed between results obtained using the present technique and those obtained using immersion scanning. P.D.

A93-19595
ULTRASONIC NDE OF ADHESIVE AND SEALANT BONDED ALUMINUM LAP-SPLICES
THADD C. PATTON and DAVID K. HSU (Iowa State Univ. of Science and Technology, Ames) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11B; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 1299-1306. Research sponsored by FAA refs
(Contract W-7405-ENG-82)
Copyright

Research samples characteristic of an actual production aircraft are employed to develop NDE methods for the inspection of adhesively bonded aluminum lap-splices. Along with realistic lap-splice samples, the inspection techniques used are ones with the potential for field or service shop applications. The practical techniques include water squirter pulse-echo and contact mode Rayleigh wave. It is found that both immersion and squirter mode ultrasonic C-scans can map out artificial defects in laboratory lap-splices with considerable detail. C-scans made from the front side indicate that the Teflon insert is between the adhesively impregnated scrim cloth layer and the top aluminum skin. Evidence is found to suggest that there is also a thin layer of adhesive applied on top of the Teflon insert. P.D.

A93-19598* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AUTOMATION OF DISBOND DETECTION IN AIRCRAFT FUSELAGE THROUGH THERMAL IMAGE PROCESSING
D. R. PRABHU (Analytical Services and Materials, Inc.; NASA, Langley Research Center, Hampton, VA) and W. P. WINFREE (NASA, Langley Research Center, Hampton, VA) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11B; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 1323-1330. refs
(Contract NAS1-18599)
Copyright

A procedure for interpreting thermal images obtained during the nondestructive evaluation of aircraft bonded joints is presented. The procedure operates on time-derivative thermal images and resulted in a disbond image with disbonds highlighted. The size of the 'black clusters' in the output disbond image is a quantitative measure of disbond size. The procedure is illustrated using simulation data as well as data obtained through experimental testing of fabricated samples and aircraft panels. Good results are obtained, and, except in pathological cases, 'false calls' in the cases studied appeared only as noise in the output disbond image which was easily filtered out. The thermal detection technique coupled with an automated image interpretation capability will be a very fast and effective method for inspecting bonded joints in an aircraft structure. P.D.

A93-19693
LARGE-AREA AIRCRAFT SCANNER
FRANK A. IDDINGS (Southwest Research Inst., San Antonio, TX) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11B; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 2233-2240. refs
(Contract F04606-89-D-0039)
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A program to determine the feasibility of present state-of-the-art NDI technology to produce a large-area scanner and to identify commercial equipment available to construct the desired system is presented. Work performed to attain these objectives is described, along with suggested modifications to the existing commercial equipment in order to meet the design criteria as closely as possible. Techniques that show the most promise at present are: D-sight, shearography, and pulse IR thermography (PIRT). D-sight is argued to be inadequate alone, but may well help form a system in conjunction with another technique. Shearography requires additional development in the area of stress application along with interpretation and overall application. PIRT is argued to be satisfactory as a large-area scanner system, at least for thin composite and metal panels. P.D.

A93-19697
ACOUSTIC EMISSION MONITORING OF AGING AIRCRAFT STRUCTURES
STUART L. MCBRIDE, MELVYN R. VINER, and MICHAEL D. POLLARD (Royal Military College of Canada, Kingston) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11B; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 2275-2282. Research supported by DND refs
Copyright

Acoustic emission monitoring of a full-scale ground durability and damage tolerance test clearly demonstrates the potential value of acoustic emission for determining 'defect zones' in large aircraft structures. Such information can then be used to focus NDT resources more effectively on damage areas. It is shown that acoustic emission monitoring is superior to conventional NDT in locating fatigue cracks, and, in addition, can be used to determine the loading conditions and loading sequences under which fatigue crack growth occurs. It is demonstrated that cracks originating inside fastener holes in aircraft structures can be readily detected by acoustic emission without the removal of fasteners. P.D.

A93-19699
P-VERSION FINITE ELEMENT MODELING FOR NDE
CAMILLE A. ISSA and KRISHNAN BALASUBRAMANIAM (Mississippi State Univ., Mississippi State) *In* Review of progress in quantitative nondestructive evaluation. Vol. 11B; Proceedings of the 18th Annual Review, Brunswick, ME, July 28-Aug. 2, 1991 New York Plenum Press 1992 p. 2307-2314. Research supported by Mississippi State Univ. refs
(Contract NSF STI-89-02064)
Copyright

The formulation for the quadrilateral element of a p-version FEM for NDE is presented. Nodal shape, side shape, and internal shape functions are derived. The problem of wave propagation in solids is investigated using a Newmark direct integration scheme applied to p-version FEM meshes. It is found that numerical noise prevails for all the time steps and along the whole structure, and that there is no apparent wave propagation phenomenon in the displacement time-history. The numerical noise suggests that the abrupt change in the element material properties between the different layers of composite material and glue resin is a fatal modeling defect. The negative effect of using higher order p-version elements and the abrupt change of the element material properties should be countered by using a greater number of elements to model each layer and higher order mapping functions in the mapping process. P.D.

A93-19914* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE USE OF INTERFEROMETRY IN THE STUDY OF ROTORCRAFT AERODYNAMICS

LAWRENCE W. CARR and YUNG H. YU (U.S. Army, Aeroflightdynamics Directorate; NASA, Ames Research Center, Moffett Field, CA) Optics and Lasers in Engineering (ISSN 0143-8166) vol. 17, no. 3-5 1992 p. 121-146. refs
Copyright

The application of interferometry techniques to analysis of aerodynamic flows on rotorcraft is reviewed, with emphasis on those studies which give insight into the character of the complex flows on helicopter rotor blades. In particular, blade-vortex interaction, dynamic stall, and transonic flow on rotor blades are reviewed, showing how interferometry offers new insight into the basic flow characteristics of these flows and presenting some of the correlations that have been made with the results of computational analysis. Author

A93-19967
THE ROLE OF NOISE IN TWO-DIMENSIONAL VORTEX MERGING
AMIT J. BASU (Indian Inst. of Science, Bangalore, India) Fluid Dynamics Research (ISSN 0169-5983) vol. 10, no. 3 Nov. 1992 p. 169-180. Research supported by Indian Inst. of Science refs
Copyright

All numerical, and some experimental studies of merging of two-dimensional vortex patches point at the existence of a critical initial distance of separation below which merging occurs and above which it does not. Some other laboratory experiments, however, report no such marked sensitivity of merging behavior on the initial distance of separation. We study the effects of noise, which is one of the possible causes of the above mentioned difference, on vortex merging. We find that noise accelerates merging, and the time needed for merging decreases nearly linearly with increasing noise for high noise levels. However, the level of noise required for merging within the advection time scale is higher than what is usually found in 'clean' wind tunnels or water tanks, and thus the presence of noise in laboratories is not the sole cause of the above difference. Author

A93-20139#
FLOW MEASUREMENTS BEHIND V-GUTTER UNDER NON-COMBUSTING CONDITION
SHIGEO HOSOKAWA, YUJI IKEDA, MASASHI MINATO, and TSUYOSHI NAKAJIMA (Kobe Univ., Japan) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0020) Copyright

In order to enhance mixing and to improve flame holding characteristics in RAM engine combustor, it is necessary to control the recirculating vortex and large scale vortex behind the flame holder. For understanding of the relation between the shape of the flame holder and the flow field behind the flameholder, the velocity measurements by fiber laser Doppler velocimeter were carried out using two types of flame holders under non-combusting condition. It is found that the rectangular section of flame holder plays a role of flow stratification. The rectangular section of the flame holder decrease the length and flow rate of the recirculating vortex and increase frequency of flow fluctuation, but did not influence the factor above-mentioned when the inlet bulk velocity changed. Author

A93-20141*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TWO-, THREE-, AND FOUR-POSTER JETS IN CROSS FLOW
THOMAS J. VUKITS, JOHN P. SULLIVAN, and S. N. B. MURTHY (Purdue Univ., West Lafayette, IN) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG3-943)
(AIAA PAPER 93-0023) Copyright

In connection with the problems of the ingestion of hot exhaust gases in engines of V/STOL and STOVL aircraft in ground effect, a series of studies have been undertaken. Ground impinging, two- and three-poster jets operating in the presence of cross flow were studied. The current paper is divided into two parts. The first part is a comparison of the low speed, two-, three-, and four-poster jet cases, with respect to the flowfield in the region of interaction between the forward and the jet flows. These include cases with mass balanced inlet suction. An analysis of the inlet entry plane of the low speed two- and three-poster jet cases is also given. In the second part, high speed results for a two jet configuration without inlet suction are given. The results are based on quantitative, marker concentration distributions obtained by digitizing video images. Author

A93-20291#
OPTIMIZATION OF ANISOTROPIC STRUCTURES CONSIDERING STRENGTH, STIFFNESS AND AEROELASTIC CONSTRAINTS
H. ROEHRLE and D. W. MATHIAS (Dornier Luftfahrt GmbH, Fiedrichshafen, Germany) Sep. 1992 8 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 refs
(AIAA PAPER 92-4796) Copyright

The DYNOPT optimization program is presented with particular attention given to the design of an anisotropic wing box. The program was used for fibers with fixed and variable directions. Design variables included cross-sectional areas, thicknesses of isotropic elements, thicknesses of layers and compounds, and orientations of anisotropic axes. Ten percent mass reduction was gained by variation of the anisotropic axes. It is concluded that the combination of finite element analysis, analytical computation, and the sequential linear programming is suitable for a wide variety of optimization problems. O.G.

A93-20293#
STRUCTURAL OPTIMIZATION WITH FREQUENCY CONSTRAINTS - A REVIEW
R. V. GRANDHI (Wright State Univ., Dayton, OH) Sep. 1992 24 p. AIAA, USAF, NASA, and OAI, Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992 refs
(Contract F33615-87-C-1550)
(AIAA PAPER 92-4813) Copyright

This paper reviews the previous work on structural optimization with frequency constraints. The sensitivity analysis, constraint approximations, and optimization algorithms are discussed in the context of frequency optimization. Frequency related issues and structural applications are presented by discussing the difficulties in designing structures with frequency constraints. Author

A93-20298* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FIBER OPTIC-BASED LASER VAPOR SCREEN FLOW VISUALIZATION SYSTEMS FOR AERODYNAMIC RESEARCH IN LARGER-SCALE SUBSONIC AND TRANSONIC WIND TUNNELS
GARY E. ERICKSON (NASA, Langley Research Center, Hampton, VA) and ANDREW S. INENAGA (Aerometrics, Inc., Sunnyvale, CA) Oct. 1992 20 p. International Flow Visualization Symposium, 6th, Yokohama, Japan, Oct. 4-9, 1992, Paper refs

The design, installation, and application of the NASA laser vapor screen (LVS) flow visualization systems developed by 10-foot high speed tunnel and 8-foot transonic pressure tunnel are discussed. Sufficient quantity of water is injected into the wind tunnel diffuser section to increase the relative humidity and promote condensation of the water vapor in the flow field about the model. Vortex-dominated flows are illuminated with an intense sheet of laser light. Fiber optics are used to deliver the laser beam through the plenum shell that surrounds the test section of each facility and to the light sheet-generating optics positioned in the ceiling window of the test section. Operational experience indicates that fiber optic-based systems are safe, reliable, and capable of proving high-quality off-surface flow visualization in larger scale subsonic and transonic wind tunnels. O.G.

A93-20302*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

COUPLED FINITE-DIFFERENCE/FINITE-ELEMENT APPROACH FOR WING-BODY AEROELASTICITY

GURU P. GURUSWAMY (NASA, Ames Research Center, Moffett Field, CA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 1-12. refs
(AIAA PAPER 92-4680) Copyright

Computational methods using finite-difference approaches for fluids and finite-element approaches for structures have individually advanced to solve almost full-aircraft configurations. However, coupled approaches to solve fluid/structural interaction problems are still in their early stages of development, particularly for complex geometries using complete equations such as the Euler/Navier-Stokes equations. Earlier work demonstrated the success of coupling finite-difference and finite-element methods for simple wing configurations using the Euler/Navier-Stokes equations. In this paper, the same approach is extended for general wing-body configurations. The structural properties are represented by beam-type finite elements. The flow is modeled using the Euler/Navier-Stokes equations. A general procedure to fully couple structural finite-element boundary conditions with fluid finite-difference boundary conditions is developed for wing-body configurations. Computations are made using moving grids that adapt to wing-body structural deformations. Results are illustrated for a typical wing-body configuration. Author

A93-20304#

FLUTTER CALCULATIONS FOR A SYSTEM WITH INTERACTING NONLINEARITIES

WOJCIECH POTKANSKI (PZL, Research and Development Center, Mielec, Poland) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 21-25. Research sponsored by DAAD refs
(AIAA PAPER 92-4682) Copyright

The iterative method is described for flutter analysis concerning nonlinear structures where nonlinearities are present only at finite number of points forming interfaces between linear sub-structures. The finite amplitude limit-cycle oscillatory motion is to be found. The structural nonlinearities are replaced by so called describing functions carried out by using the harmonic linearization method. The classical flutter equation is employed, and only the stiffness matrix is modified during the iteration process. The sample of numerical results shows the application of the iterative method to the flutter analysis of a glider with a nonlinear control system. Author

A93-20326

ANALYSIS OF THE NASA HYPERSONIC WING TEST STRUCTURE

GLENN MORRIS (General Dynamics Corp., Fort Worth, TX) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 272-287. refs
(AIAA PAPER 92-4724) Copyright

A fully integrated finite element method encompassing structural, thermal, and aerodynamic analysis was applied to the evaluation of the Hypersonic Wing Test Structure (HWTS), a heavily instrumented demonstration component simulating the wing of a Mach-8 aircraft. The HWTS was tested under a combination of mechanical loads and heating time histories. Results for each of several analysis grids are presented, demonstrating good correlation with experimental data. Details of the method, tentatively called LIFTS (Langley Integrated Fluid-Thermal-Structural Analysis), are described. V.L.

A93-20329#

AEROELASTIC MODEL DESIGN USING STRUCTURAL OPTIMIZATION

MARK FRENCH (USAF, Wright Lab., Wright-Patterson AFB, OH) and F. E. EASTEP (Dayton Univ., OH) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 323-331. refs
(AIAA PAPER 92-4730)

The testing of aeroelastically scaled with tunnel models is a common task in flight vehicle development programs. The object of the testing is often to verify the numerically predicted aeroelastic characteristics of an entire vehicle or some component of it. The design process can be very involved, so an effort has been made to use optimization methods to automate it. The model design process has been divided into separate stiffness design and mass design stages. Five different stiffness design approaches and two different mass design approaches were evaluated using a low aspect ratio fighter wing as a sample problem. Different design methods are compared and a final design is produced. After a model was designed using the different methods, a sample structure was manufactured and subjected to static and modal testing using laser holographic techniques. Author

A93-20352#

STRUCTURAL OPTIMIZATION USING NEWTON MODIFIED BARRIER METHOD

N. S. KHOT (USAF, Wright Lab., Wright-Patterson AFB, OH), R. POLYAK, and R. SCHNEUR (IBM T.J. Watson Research Center, Yorktown Heights, NY) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 543-550. refs
(AIAA PAPER 92-4756)

The Newton Modified Barrier Method (NMBM) was applied to a structural optimization problem with large numbers of design variables and constraints. This mathematical optimization algorithm was based on Modified Barrier Function (MBF) theory and the global converging step version of the Newton Method for smooth unconstrained optimization. For illustrating the convergence characteristics of this method to structural optimization, a truss structure with 721 design variables with constraints on displacements and minimum size requirements was solved. The convergence to the optimum was found to be monotonic. The rate of convergence was compared with solving the same problem with ASTROS and optimality criteria approach. Author

A93-20420

THERMAL/STRUCTURAL ANALYSIS AND AIRCRAFT DESIGN

Aerospace Engineering (ISSN 0736-2536) vol. 12, no. 12 Dec. 1992 p. 9-12.
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A process that enables a thermal engineer to provide accurate temperature distributions for large structural models (consisting of greater than 8000 elements) in two weeks was developed. Geometry information is provided by the structural designer to the thermal and structural engineers. Solutions are obtained using thermal boundary conditions for the thermal finite elements, and structural boundary conditions for the structural finite elements. The results are reviewed to make any required structural design modifications or changes in material selection. The process is iterated until the adequate design is obtained. O.G.

A93-20644

PHOTOELECTROCHEMICAL ETCHING OF HIGH ASPECT RATIO SUBMILLIMETER WAVEGUIDE FILTERS FROM N(+) GAAS WAFERS

R. KHARE, E. L. HU, D. REYNOLDS, and S. J. ALLEN (California Univ., Santa Barbara) Applied Physics Letters (ISSN 0003-6951) vol. 61, no. 24 Dec. 14, 1992 p. 2890-2892. Research

supported by Xerox Corp. refs
(Contract N00014-56-J-0011; NSF DMR-91-20007)
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A 200-micron high-pass filter has been fabricated using the photoelectrochemical (PEC) etch process to form a series of waveguides through a Si-doped n(+) GaAs (1 x 10 exp 18/cu cm) substrate. A metal mask on the sample surface with 100-micron square openings and 41-micron spaces was used to locally prevent PEC etching. The sample was etched in a (4:1:50) HCl:HNO3:H2O electrolyte for 1.5 h using an argon ion laser (514 nm) at an intensity of 0.7 W/sq cm, and an applied bias of 0.35 V. The result was a series of highly anisotropic waveguides with a (3:1) aspect ratio. The transmittance curve had a cutoff of 45/cm and a transmittance of 20 percent just above the cutoff. Author

A93-20714
STRUCTURAL NON-LINEARITY EFFECTS ON FLUTTER OF A SWEPT WING IN TRANSONIC FLOWS
I. W. TJATRA, R. K. KAPANIA, and B. GROSSMAN (Virginia Polytechnic Inst. and State Univ., Blacksburg) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 131-138. refs
Copyright

The transonic flutter analysis of swept wings containing structural nonlinearities is considered. Concentrated preload nonlinearities are treated using asymptotic expansions which take into account the influence of the higher harmonics of the load-displacement expansion series. The generalized aerodynamic load matrix is obtained using pulse transfer function analysis. Transonic aerodynamic flows are modeled using the transonic small-disturbance equation which is solved by applying an approximate factorization finite-difference algorithm. The frequency domain solutions of the aeroelastic equation is obtained through root-locus analysis. The effects of the magnitudes of the preload nonlinearities on the flutter stability boundary of the system are studied. Author

A93-20719* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NUMERICAL SIMULATION OF SHOCK-INDUCED COMBUSTION/DETONATION
D. J. SINGH (Analytical Services and Materials, Inc., Hampton, VA), J. K. AHUJA (Old Dominion Univ., Norfolk, VA), and M. H. CARPENTER (NASA, Langley Research Center, Hampton, VA) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 201-215. refs
Copyright

A numerical study is conducted to simulate the shock-induced combustion in premixed H2-air mixtures. Two types of bodies, blunt (spherical projectile) and sharp (wedge), are considered in the study. A nine-species, 18-step finite-rate H2-air chemical reaction mechanism coupled with the Navier-Stokes equations is solved. The flow field over the blunt body is found to be unsteady, when the projectile velocity is same as the Chapman-Jouget velocity of the mixture. The unsteadiness is caused by the periodic instabilities originating in the stagnation zone. Numerical results show good qualitative agreement with the ballistic range shadowgraph. In addition, the frequency of oscillations, determined by using the Fourier power spectrum, is found to be in good agreement with the experiment. The flow field over the wedge is found to be stable for the conditions considered in this study. The oblique detonation wave structure is investigated and the important flow features are discussed. Author

A93-20920
AIRCRAFT EXPERIMENTS ON MICROGRAVITY POOL BOILING - VAPOR-LIQUID BEHAVIOUR AND HEAT TRANSFER CHARACTERISTICS IN BOILING OF N-PENTANE, CFC-113 AND WATER
TOSHIHARU OKA, YOSHIYUKI ABE, YASUHIKO H. MORI, and AKIRA NAGASHIMA Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58 June 1992 p. 1867-1874. In Japanese. refs
Copyright

Boiling of n-pentane, CFC-113 and water under microgravity were studied, utilizing parabolic flight maneuvers with a Caravelle aircraft. The experimental apparatus was constructed so as to permit simultaneous video recording of the side view of vapor bubbles, generated on a Joule-heated, transparent indium-oxide film plated on a glass substrate, and the backside view through the substrate. The heat transfer to n-pentane or CFC-113 in the nucleate-boiling regime deteriorated slightly under microgravity, while the critical heat flux was lowered to two-fifths of the corresponding terrestrial value. In contrast, the heat transfer to water significantly deteriorated under microgravity. The difference in the degree of heat transfer deterioration thus observed is presumably ascribed to a considerable difference, between the former two liquids and water, in the bubble behavior in the vicinity of the heater surface, which in turn must depend on the surface tension of each liquid and the wettability of the heater surface with the liquid. Author

A93-21085
EMBEDDED FIBER OPTIC SENSORS IN LARGE STRUCTURES
ERIC UDD (McDonnell Douglas Electronic Systems Co., Santa Ana, CA) *In* Fiber optic smart structures and skins IV; Proceedings of the Meeting, Boston, MA, Sept. 5, 6, 1991 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 178-181. refs
Copyright

A possible line replaceable fiber optic sensor system compatible with future aircraft requirements is described which could be used to support health monitoring and damage assessment functions to augment survivability, repairability, and maintainability while enhancing performance and control systems by providing flexible sensor information channels. The architecture of an embedded sensor system is described, with attention given to the selection of sensors to support it. V.L.

A93-21094
APPLICATION ISSUES OF FIBER OPTIC SENSORS IN AIRCRAFT STRUCTURES
Z. J. LU and F. A. BLAHA (Canadian Marconi Co., Avionics Div., Montreal, Canada) *In* Fiber optic smart structures and skins IV; Proceedings of the Meeting, Boston, MA, Sept. 5, 6, 1991 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 276-281. Research supported by DND refs
Copyright

This paper considers two important application issues of fiber optic sensors in aircraft structures. The first concerns the interfacing of optical fibers with composite material structures: concepts have been developed for realizing a reliable exit point for the embedded fiber from a composite aircraft component, by means of single-mode connector assemblies embedded in composite material structures. The second issue relates to the temperature stability of the sensors: temperature characteristics of two-mode fiber optic strain sensors were investigated, sensors made of elliptical core and bow-tie fibers are compared, and the trade-offs among strain sensor range, sensitivity and temperature stability are discussed. Author

A93-21629
FINDING FAULT WITH AVIONICS
ALAN S. BROWN Aerospace America (ISSN 0740-722X) vol. 31, no. 1 Jan. 1993 p. 32-37.
Copyright

This paper reviews new design and testing approaches that may increase electronics reliability by uncovering flaws before they cause failures. Some preliminary results show that half of all failures are the result of design problems that lead to electrical overstress. Avionics developers are improving materials for printed circuit board construction and designing more fault-tolerant systems. R.E.P.

A93-21653
INFLUENCES ON THE SPRAYS FORMED BY HIGH-SHEAR FUEL NOZZLE/SWIRLER ASSEMBLIES
J. M. COHEN and T. J. ROSFJORD (United Technologies Research Center, Hartford, CT) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 16-27. Previously cited in issue 18, p. 2889, Accession no. A90-42068 refs
(Contract F33615-85-C-2515)
Copyright

A93-21659
ADVANCED DIRECT-DESIGN PROCEDURE FOR CENTRIFUGAL IMPELLERS
SARUM N. J. AL-ZUBAIDY (United Arab Emirates Univ., Al-Ain) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 67-73. refs
Copyright

The design of centrifugal impellers usually starts with a preliminary design making use of one-dimensional flow analysis thus enabling the skeletal dimensions of the impeller to be determined. This is followed by a detailed design that requires the complete description of the three-dimensional geometry which is subsequently modified by means of successive aerodynamic analysis (indirect approach). The initial description of the blade geometry relies heavily on the experience and the engineering judgement of the designer. This article will present a method that will replace this arbitrary stage of the design sequence by a design procedure that will effectively generate the three-dimensional coordinate of impellers designed for a prescribed velocity schedule (direct-design approach). The study suggests that the degree of blade wrapping could - and was controlled by - adjusting the magnitude and the distribution characteristics of the relative pressure loading parameter. The leaning of the mean streamline forward is caused by increasing the loading distribution while a background lean is achieved by decreasing the blade loading. The rate at which the radial relative velocity accelerates was used to eliminate undesirable blade curvatures during the design procedure. Author

A93-21660
WAKE INGESTION PROPULSION BENEFIT
LEROY H. SMITH, JR. (GE Aircraft Engines, Cincinnati, OH) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 74-82. Previously cited in issue 17, p. 2934, Accession no. A91-41676 refs
Copyright

A93-21665
EVALUATION OF BRUSH SEALS FOR LIMITED-LIFE ENGINES
RAYMOND E. CHUPP (Teledyne CAE, Toledo, OH) and PAUL NELSON (USAF, Wright Lab., Wright-Patterson AFB, OH) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 1 Jan.-Feb. 1993 p. 113-118. Previously cited in issue 18, p. 2897, Accession no. A90-42040 Research supported by Teledyne CAE refs
(Contract F33615-88-C-2836)

A93-21688
FLOW FIELD CHARACTERISTICS OF AN AXISYMMETRIC SUDDEN-EXPANSION PIPE FLOW WITH DIFFERENT INITIAL SWIRL DISTRIBUTION
A. S. NEJAD and S. A. AHMED (USAF, Experimental Research Branch, Wright-Patterson AFB, OH) International Journal of Heat and Fluid Flow (ISSN 0142-727X) vol. 13, no. 4 Dec. 1992 p. 314-321. Research supported by USAF refs
Copyright

The results of an experimental investigation depicting the effects of swirl profile on confined flows in a sudden-expansion coaxial dump combustor are presented. Three swirlers (free vortex, forced vortex, and constant angle) with the same nominal swirl number were designed and fabricated to study the effects of swirl type on the isothermal dump combustor flow field. Imparting swirl to the inlet flow resulted in a considerable reduction of the corner recirculation length, a marked increase in turbulent mixing activity, and in one case creation of a central recirculation zone. This article highlights the importance of the combustor inlet swirl profile and shows that swirl type as well as swirl strength can affect the flow field significantly. The present database is well suited for numerical codes development and validation. Author

A93-21729
AUGMENTATION OF TURBULENT HEAT TRANSFER WITH A VORTEX GENERATOR ATTACHED TO A LEBU PLATE
KYOJI INAOKA, KAZUYUKI SUZUKI, HIROSHI SUZUKI, YOSHIMICHI HAGIWARA, and KENJIRO SUZUKI Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58, no. 551 July 1992 p. 2241-2247. In Japanese. refs
Copyright

An experimental study was conducted to determine if the deterioration in heat transfer caused by the insertion of a large eddy break-up manipulator (LEBU plate) could be recovered by attaching a half-delta wing vortex generator to the LEBU plate. The vortex generator was found to work well to augment the wall heat transfer over a large streamwise distance, although the LEBU plate itself is expected to eliminate the large-scale eddy motion in the boundary layer. Some geometric parameters of the inserted LEBU plate attached to the vortex generator were varied in several steps. Within the experimental ranges of such parameters, the height and angle of attack of the vortex generator were found to seriously affect the magnitude of heat transfer augmentation, which becomes more pronounced as both of their values are increased. Author

A93-21739
DEVELOPMENT OF A SHAPE-CONTROLLED AIRFOIL BY USE OF SMA
HIROSHI TSUKAMOTO, KAZUHIRO TANAKA, SHIGENORI MATSUNAGA, and HIROKI TANAKA Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58, no. 552 Aug. 1992 p. 2493-2497. In Japanese. refs
Copyright

A Shape-controlled airfoil was developed by use of shape memory alloys (SMA). Two-way change in the blade shape was realized by use of a differential two-way element in which the two different shapes were memorized. The developed airfoil was tested in the wind tunnel in order to check the effect of the shape change on the characteristics of the airfoil. Flow visualization experiments in a smoke tunnel as well as the traverse of the wake behind the airfoil showed that the shape change by electrically heated SMA gives a marked change in flow around the airfoil near the stall angle of the original shape. As the result of this study, it was found that the developed SMA actuator is effective for the control of flow separation from the blade surface. Author

A93-21743
CHARACTERISTICS OF LIQUID JET ATOMIZATION ACROSS A HIGH-SPEED AIRSTREAM. I - EXPERIMENT ON SHAPE OF SPRAY, SPATIAL DISTRIBUTION OF INJECTED LIQUID AND SAUTER MEAN DIAMETER
TETSUYA ODA, HIROYUKI HIROYASU, MASATAKA ARAI, and KEIYA NISHIDA Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58, no. 552 Aug. 1992 p. 2595-2601. In Japanese. refs
Copyright

To elucidate the atomization process of a liquid jet across a high-speed airstream, the spray shape, the mass flow rate per unit area and the Sauter mean diameter were measured. Under an airstream velocity of 140 m/s or 70 m/s and injection velocity of 10 m/s, 20 m/s or 40 m/s, the Sauter mean diameter and the maximum liquid mass flow rate per unit area in the spray hardly changed with the liquid injection velocity. However, with increasing air velocity, the Sauter mean diameter decreased and the maximum liquid mass flow rate per unit area increased. Rearranged spatial distribution of the liquid mass flow rate per unit area in a horizontal direction agreed with the profile by the Gauss's function. An equation for width of spray was obtained from the photographic results. Author

A93-21744
CHARACTERISTICS OF LIQUID JET ATOMIZATION ACROSS A HIGH-SPEED AIRSTREAM. II - CALCULATION OF SPATIAL DISTRIBUTION OF LIQUID, VARIATION OF DROP DIAMETER AND DROP TRAJECTORY
TETSUYA ODA, HIROYUKI HIROYASU, MASATAKA ARAI, and KEIYA NISHIDA Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58, no. 552 Aug. 1992 p. 2602-2606. In Japanese. refs
Copyright

To elucidate the atomization process of a liquid jet across a high-speed airstream, the spatial distribution of liquid, drop diameter and drop trajectory were calculated. In this mode, a liquid column is not incorporated. Drops ejected from the injector have the same velocity Vt but different drop diameter, which are defined by the volume distribution of drop size. The ejected drop is broken up by the airstream. Calculated spatial distribution of liquid agrees well with measured spatial distribution of liquid. The trend of the calculated drop diameters agreed well with the trend of the measured Sauter mean diameter. The drop diameter decreases rapidly, near the injector especially along the outer line of the spray. Author

A93-21840
ADVANCED AEROSPACE HYDRAULIC SYSTEMS AND COMPONENTS
Warrendale, PA Society of Automotive Engineers, Inc. (SAE SP-885) 1991 98 p.
(SAE SP-885; ISBN 1-56091-179-4) Copyright

The present volume discusses the development of a viable hydraulic circuit breaker, the electromodulated control of supply pressure in hydraulic systems, the flight control actuation system for the B-2 advanced technology bomber, and the B747-400 upper rudder control system with triple tandem valve. Also discussed are a total-flexibility cartridge-valve porting via innovative sealing technology, the A320 pilots' autothrust survey, an all-digital electrohydrostatic servoactuator, and a concurrent design/analysis tool for aircraft hydraulic systems. (For individual items see A93-21841 to A93-21844) O.C.

A93-21842
ELECTRO-MODULATED CONTROL OF SUPPLY PRESSURE IN HYDRAULIC SYSTEMS
PAUL LAWHEAD (Abex Corp., Aerospace Div., Oxnard, CA) *In* Advanced aerospace hydraulic systems and components Warrendale, PA Society of Automotive Engineers, Inc. 1991 p. 11-17.
(SAE PAPER 912119) Copyright

After noting the hydraulic power requirements of representative military aircraft, attention is given to the inefficiencies of the higher-pressure systems being considered for high horsepower and to the approaches available for superior management of high pressure/horsepower requirements. The benefits obtainable through variable-pressure system designs are illustrated; such systems gain a beneficial synergy from the combination of hydraulics and electronics. O.C.

A93-21857
A RAPID PROCEDURE FOR OBTAINING TIME-AVERAGE INTERFEROGRAMS OF VIBRATING BODIES
ELIEZER RAPOPORT, DORON BAR, and KLARA SHILOH (Israel Atomic Energy Commission, Soreq Nuclear Research Centre, Yavne) *In* Meeting in Israel on Optical Engineering, 7th, Tel Aviv, Israel, Nov. 12-14, 1990, Proceedings Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 383-391. refs
Copyright

A method for vibrational analysis by time-average holographic interferometry was developed, based on conventional holography, and especially suitable for laboratories not equipped with ESPI system. It overcomes the main drawback of conventional time-average rocording: the inhibitively cumbersome procedure which requires recording a new hologram for each set of vibrational parameters. Only one holographic recording of the tested object at rest is needed, and image processing techniques are used to construct time-average holographic pictures of the vibrating body over any desired frequency (and amplitude) range. The method is simple, almost as rapid as ESPI (approaching real time), yielding pictures of good quality and fine details with resolution limited by that of the TV camera used. The method was applied to, and is demonstrated in the determination of vibrational modes of jet-engine blades. Author

A93-21878
PROPAGATION OF TRANSVERSE ANTI-PLANE WAVES IN ORTHOTROPIC LAYERS
M. A. G. SILVA (Lab. Nacional de Engenharia e Tecnologia Industrial, Lisbon, Portugal) European Journal of Mechanics, A/Solids (ISSN 0997-7538) vol. 11, no. 6 1992 p. 849-862. refs
Copyright

The problem of wave propagation in stratified solid media is examined for both isotropic and orthotropic layers. For isotropic materials, the response is found to depend on two parameters for propagation normal to the layers: the ratio of the impedances and the ratio of the times required for waves to travel across each layer. These parameters contain the necessary information for determining the width of the stopbands and passbands. For the case of orthotropic layers, the effect of the ratios of orthotropy for each layer and of their relative magnitudes on the attenuation bands and on their nonexistence is established. V.L.

A93-21922
NONEQUILIBRIUM EXCITATION OF INTERNAL MOLECULAR DEGREES OF FREEDOM IN THE SHOCK LAYER DURING HYPERSONIC FLIGHT
V. M. DOROSHENKO, N. N. KUDRIAVTSEV, and V. V. SMETANIN (Moscow Inst. of Physics and Technology, Dolgoprudny, Russia) Shock Waves (ISSN 0938-1287) vol. 2, no. 3 1992 p. 139-146. refs
Copyright

A kinetic scheme of processes including the formation and quenching of electronically and vibrationally excited particles is proposed for the shock layer adjacent to the surface of a body flying at hypersonic speed. We present results of a numerical calculations for the stagnation point obtained under the thin viscous shock layer approximation for space shuttle flight conditions. We show that the release of atom recombination energy into the internal molecular degrees of freedom and the finite rate of relaxation reduce the calculated heat flux by 20 percent. Author

A93-21934
AN OVERVIEW OF THE EVOLUTION OF VIBRATING BEAM ACCELEROMETER TECHNOLOGY
B. L. NORLING (Sundstrand Data Control, Inc., Washington) *In* Symposium Gyro Technology 1991, Stuttgart, Germany, Sept. 24, 25, 1991, Proceedings Stuttgart/Duesseldorf Universitaet Stuttgart/Deutsche Gesellschaft fuer Ortung und Navigation 1991 p. 7.0-7.31. refs

The history of vibrating beam accelerometers (VBA) is briefly outlined, and the current status of VBA technology is reviewed. In particular, attention is given to the VBA design fundamentals and the performance characteristics of several state-of-the-art VBA models. Finally, prospects for the future development of VBAs and the effect of VBA technology on the inertial navigation industry are discussed. V.L.

A93-22173
ELEVATED ARRAY DETECTION AND MEASUREMENT OF MICROBURSTS USING THETA(E)
PETER J. ECCLES *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 341-344. Research sponsored by Mitre Corp refs
Copyright

The study describes research to develop an inexpensive,

accurate, operational solar powered digital meteorological sensor and to deploy an elevated array of these in order to achieve a high confidence of detecting and locating all microbursts striking the array. Attention is given to work to deploy these economic, total-pressure, and equivalent-potential-temperature-measuring arrays in places in which there are no plans to detect microbursts at this time, such as secondary, general-aviation, and third-world airports. It is postulated that changes in the meteorological properties of the area near the ground, not just wind speed, can be measured and can indicate the presence of a microburst. It is shown that microbursts can be located and measured by elevated arrays of meteorological sensors. P.D.

A93-22176
AN AUTOMATED SYSTEM FOR THE MEASUREMENT OF SLANT VISUAL RANGE
EDWARD M. PATTERSON and GARY G. GIMMESTAD (Georgia Inst. of Technology, Atlanta) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 357, 358. refs
Copyright
The paper examines efforts to develop an automated system for the measurement of slant visual range (SVR) that would provide a greatly expanded set of data to pilots on approach paths and could lead to significant changes in aircraft operations. System specifications for a lidar-based system for measuring SVR under a variety of reduced visibility conditions have been developed. The system includes a high-performance eyesafe lidar, a computer and operating software for automated operation and data analysis, and a communications system for data output. P.D.

A93-22178
ANEMOMETER SITING CRITERIA FOR LOW LEVEL WIND SHEAR ALERT SYSTEM
JON A. PETERKA (Cermak Peterka Petersen, Inc., Fort Collins, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 365-369. Research supported by NCAR refs
(Contract DTFA05-89-C-79042)
Copyright
The development of an anemometer siting guide for Federal Aviation Administration use is described. The siting guide included the influence of change in surface roughness, placement within a forest with upwind fetch, the influence of 2D obstacles such as tree lines, the influence of 3D bluff obstacles such as buildings or clumps of trees, the influence of forests on winds downwind of the end of the forest, the influence of 2D and 3D isolated hills on the acceleration of flow over a hilltop, and shielding downwind of hills. A physical model study was performed in a boundary layer wind tunnel capable of simulating wind flow in the atmospheric boundary layer. Profiles of mean velocity were measured for neutrally stable wind flow over proposed anemometer sites to determine the minimum anemometer height required to escape most the shielding effects of the surroundings. Wind velocity profiles in complex terrain compared to runway wind speed are illustrated. P.D.

A93-22265* National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SOME UNSTEADY FLUID FORCES ON PUMP IMPELLERS
R. S. MISKOVISH and C. E. BRENNEN (California Inst. of Technology, Pasadena) ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202) vol. 114, no. 4 Dec. 1992 p. 632-637. refs
(Contract NAS8-33108)
Copyright
Special analyses of all the forces and moments acting on a typical centrifugal pump impeller/volute combination are presented. These exhibit shaft frequencies, blade passing frequencies, and beat frequencies associated with a whirl motion imposed on the shaft in order to measure rotordynamic forces. Among other features the unsteady thrust was found to contain a surprisingly large blade passing harmonic. While previous studies have explored the magnitudes of the steady fluid-induced radial forces and the fluid-induced rotordynamic forces for this typical centrifugal pump impeller/volute combination, this paper presents information on the steady bending moments and rotordynamic moments due to the fluid flow. These imply certain axial locations for the lines of action of the radial and rotordynamic forces. Data on the lines of action are presented and allow inferences on the sources of the forces. Author

A93-22294#
ON THE COUPLED THERMOMECHANICAL ANALYSIS OF HYPERSONIC FLIGHT VEHICLE STRUCTURES
ONUR R. ODABAS (Ohio State Univ., Columbus) and NESRIN SARIGUL-KLIJN (California Univ., Davis) Dec. 1992 13 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5018) Copyright
A comparative numerical study of the coupled versus uncoupled thermal-structural analysis of viscoplastic solids is presented. In this study, deformations are assumed to be infinitesimal and material properties are approximated by a unified viscoplastic strain-hardening constitutive model. For both analyses, the Galerkin Finite Element Method is utilized along with a time marching scheme to predict the quasi-static thermomechanical behavior of inelastic solids with rate and temperature-dependent material properties. In the coupled analysis, the displacements and temperature distribution at every time step are computed at once by solving the system of equations directly. The results indicate that the magnitude of coupling decreases with the increase in temperature and the decrease in internal dissipation. This trend seems to be valid for all engineering materials. Author

A93-22312*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HEAT FLUX MICROSENSOR MEASUREMENTS
J. P. TERRELL, J. M. HAGER (Vatell Corp., Christiansburg, VA), S. ONISHI, and T. E. DILLER (Virginia Polytechnic Inst. and State Univ., Blacksburg) Dec. 1992 9 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 Research supported by NASA refs
(AIAA PAPER 92-5038) Copyright
A thin-film heat flux sensor has been fabricated on a stainless steel substrate. The thermocouple elements of the heat flux sensor were nickel and nichrome, and the temperature resistance sensor was platinum. The completed heat flux microsensor was calibrated at the AEDC radiation facility. The gage output was linear with heat flux with no apparent temperature effect on sensitivity. The gage was used for heat flux measurements at the NASA Langley Vitiated Air Test Facility. Vitiated air was expanded to Mach 3.0 and hydrogen fuel was injected. Measurements were made on the wall of a diverging duct downstream of the injector during all stages of the hydrogen combustion tests. Because the wall and the gage were not actively cooled, the wall temperature reached over 1000 C (1900 F) during the most severe test. Author

A93-22330#
PENETRATION AND MIXING OF BUBBLING LIQUID JETS FROM MULTIPLE INJECTORS NORMAL TO A SUPERSONIC AIR STREAM
TAKAKAGE ARAI (Muroran Inst. of Technology, Japan) and JOSEPH A. SCHETZ (Virginia Polytechnic Inst. and State Univ., Blacksburg) Dec. 1992 9 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5060) Copyright
Liquid and bubbling jets are injected from multiple injectors normal to a $M = 2.4$ airflow and the flow patterns are observed photographically. The penetration and width of the jet plumes are measured utilizing nanoshadowgraphs and front-lighted pictures, respectively. These experiments are conducted at constant supply pressure and constant liquid mass flow rate conditions. R.E.P.

A93-22333#
NUMERICAL AND EXPERIMENTAL INVESTIGATION OF MIXING ENHANCEMENT IN SCRAMJETS
R. RAUL, H. E. GILREATH, and G. A. SULLINS (Johns Hopkins Univ., Laurel, MD) Dec. 1992 6 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(Contract N00039-91-C-0001)
(AIAA PAPER 92-5063) Copyright

The mixing of two supersonic streams in a confined region is simulated using the turbulent Navier-Stokes equations. The wall was assigned a sinusoidal shape to represent a configuration that might increase the rate of growth of the mixing layer via 'spatial forcing'. The effect of varying the amplitude of the wavy wall was investigated. Based on the numerical results presented here, some conclusions are drawn regarding the loss of total pressure and stream thrust in this type of flowfield. The Mach number distribution along the wavy walls was used to predict the onset of flow separation for a particular configuration. Author

A93-22360#
REMOTE SENSING OF O2 IN A SUPERSONIC COMBUSTOR USING DIODE LASERS AND FIBER OPTICS
J. R. VEALE, L. G. WANG, and T. F. GALLGHER (Virginia Univ., Charlottesville) Dec. 1992 9 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5090) Copyright

A compact, remote sensing laser absorption spectrometer has been built and interfaced to a supersonic combustor at the NASA Langley Research Center Hypersonic Propulsion Facility. The spectrometer is based around a GaAs diode laser, fiber optics, and the wavelength modulation spectroscopic technique. Two oxygen A-band transitions were monitored in the flow as a function of time and from the resulting second harmonic lineshapes temperature and density were determined. Author

A93-22509*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EVALUATION AND APPLICATION OF THE BALDWIN-LOMAX TURBULENCE MODEL IN TWO-DIMENSIONAL, UNSTEADY, COMPRESSIBLE BOUNDARY LAYERS WITH AND WITHOUT SEPARATION IN ENGINE INLETS
BARBARA SAKOWSKI, DOUGLAS DARLING (NASA, Lewis Research Center, Cleveland, OH), ROBERT L. ROACH (Georgia Inst. of Technology, Atlanta), and ALLAN VAN DE WALL (Case Western Reserve Univ., Cleveland, OH) Jul. 1992 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 28th, Nashville, TN, July 6-8, 1992 Previously announced in STAR as N93-10087 refs
(AIAA PAPER 92-3676) Copyright

The Baldwin-Lomax model is used in many CFD codes because it is quick and easy to implement. In this paper, we discuss implementing the Baldwin-Lomax turbulence model for both steady and unsteady compressible flows. In addition, these flows may be either separated or attached. In order to apply this turbulence model to flows which may be subjected to these conditions, certain modifications should be made to the original Baldwin-Lomax model. We discuss these modifications and determine whether the Baldwin-Lomax model is a viable turbulence model that produces reasonably accurate results for high speed flows that can be found in engine inlets. Author

A93-22588*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
COMPUTATION OF NONEQUILIBRIUM RADIATING SHOCK LAYERS
TAHIR GOKCEN (Eloret Inst., Palo Alto; NASA, Ames Research Center, Moffett Field, CA) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NCC2-420)
(AIAA PAPER 93-0144) Copyright

A computational technique of coupling radiative transfer to fluid motion is developed for axisymmetric blunt body shock layer flows in a thermochemical nonequilibrium environment. The coupled formulation of radiation and flowfield leads to a governing set of integro-differential equations. This equation set is solved using a modified Gauss-Seidel line relaxation techniques which incorporates the inversion of full block matrix associated with radiative transfer using a block iteration method. The thermodynamic state of the gas is described by three temperatures: translational, rotational, and vibrational-electronic. Radiation phenomenon is assumed to be governed by the vibrational-electronic temperature. The radiative properties are described by a spectrally detailed model. The computations are presented for two cases, including the Fire II flight experiment. It is shown that the method converges and the calculated spectra qualitatively agree with the experimental data for the two test cases. The calculated total radiative flux underestimates the measured values owing to the low vibrational-electronic temperature predicted in the flowfield calculation. Author

A93-22605#
DATA ANALYSIS TECHNIQUES FOR PRESSURE- AND TEMPERATURE-SENSITIVE PAINT
J. F. DONOVAN, M. J. MORRIS, A. PAL, M. E. BENNE, and R. C. CRITES (McDonnell Douglas Aerospace, Saint Louis, MO) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0176) Copyright

Pressure- and temperature-sensitive paint measurements can be used to obtain global information on a surface. Application of these techniques in practical situations has illustrated several data analysis problems. These include model displacement and model bending, transformation from image to model coordinates, and camera lens distortion. Methods which deal with these problems are presented in conjunction with results indicating the degree of success. Results are taken from recent tests of an advanced fighter, a transport wing, and a shock-wave/boundary layer interaction. Author

A93-22607*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
VIDEO LUMINESCENT BAROMETRY - THE INDUCTION PERIOD
RORY H. UIBEL, GAMAL KHALIL, MARTIN GOUTERMAN, JEAN GALLERY, and JAMES B. CALLIS (Washington Univ., Seattle) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Boeing Co. refs
(Contract NCA2-485; NCA2-500)
(AIAA PAPER 93-0179) Copyright

Video monitoring of oxygen quenching of the photoluminescence of platinum octaethylporphyrin (PtOEP) in silicone polymer resin may be used to measure pressure distribution over an airfoil. A continuous increase of the luminescence intensity of PtOEP on exposure to the exciting light is known as the induction effect. The effect of several factors on PtOEP photoluminescence and the induction effect was investigated. The experimental apparatus is described and results are presented. It was observed that the relative induction amplitude and induction time increase at higher oxygen pressure and with thicker films. These observations may be explained if the singlet oxygen produced by oxygen quenching is consumed by the polymer and is therefore unavailable for further quenching. Researchers using this method for measuring pressure distribution on airfoil surfaces should be aware of the induction effect and its implications. A.O.

A93-22608*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TWO-DIRECTIONAL SKIN FRICTION MEASUREMENT UTILIZING A COMPACT INTERNALLY MOUNTED THIN-LIQUID-FILM SKIN FRICTION METER
JEFFREY A. SETO and HANS G. HORNUNG (California Inst. of Technology, Pasadena) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993

refs
(Contract NAG2-621)
(AIAA PAPER 93-0180) Copyright

A new, compact oil film skin friction meter capable of measuring skin friction in two directions has been designed and constructed. The instrument allows the thin liquid film technique to now be applied in flight and in a wider variety of laboratory conditions. The instrument was tested by comparing measurements with those given by a floating element gage in laminar, transitional, and turbulent boundary layers with zero pressure gradient. Both instruments agreed satisfactorily with each other and with the expected curves for the laminar and turbulent boundary layers. Significant differences were at first seen between the oil film meter and two floating element gages in the case of a favorable pressure gradient, but when a correction is applied to account for the normal force acting on the pendulum-type gage, the three instruents are much closer. The directional sensitivity of the oil film gage is also demonstrated. Author

A93-22635#
VORTICAL AND TURBULENT STRUCTURE OF A LOBED MIXER FREE-SHEAR LAYER
D. C. MCCORMICK (United Technologies Research Center, East Hartford, CT) and J. C. BENNETT, JR. (Connecticut Univ., Storrs) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by United Technologies Corp refs
(AIAA PAPER 93-0219) Copyright

An experimental investigation of the vortical and turbulent structure in a free-shear layer downstream of a lobed mixer has been conducted. Pulsed-laser sheet flow visualization with smoke and three-dimensional velocity measurements with hot film anemometry were obtained for a lobed-mixer configuration and a baseline, planar configuration. Both laminar and turbulent initial boundary layer conditions were documented for both cases. The main results of this investigation is that a new vortex structure was found to exist for the lobed mixer in addition to the well-known stream-wise vortex array. The normal vortex (due to the Kelvin-Helmoltz instability) sheds periodically from the convoluted trailing edge of the lobed mixer and plays a major part in the enhanced mixing process in combination with the streamwise vorticity. The streamwise vorticity deforms the normal vortex into a pinched-off structure that creates intense small-scale turbulence and mixing. The shear layer growth rate for the first 5-6 lobe heights is substantially greater than the planar free-shear layer; however, downstream of six lobe heights the growth rate slows considerably to a rate below that of the planar configuration due to the double-layered shear layer structure of the lobed mixer and the corresponding reduced turbulent kinetic energy. Author

A93-22638#
VISUALIZATION OF VORTICAL FLOWS WITH YET ANOTHER POST-PROCESSOR
DAVY M. BELK and RAYMOND C. MAPLE (USAF, Wright Lab., Eglin AFB, FL) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0222)

A new general purpose CFD post processor (yapp) with special features for studying vortical flows is presented. The yapp program is described with emphasis on its particle trace generation and display capabilities. Various methods of approaching the vortical flow visualization problem are discussed, with the stream surface identified as the preferred method. Examples of flowfield visualization for a high alpha delta wing, a supersonic blunt fin, and a high alpha ogive cylinder are presented. Author

A93-23021#
3-D ADAPTIVE GRID-EMBEDDING EULER TECHNIQUE
ROGER L. DAVIS and JOHN F. DANNENHOFFER, III (United Technologies Research Center, East Hartford, CT) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by United Technologies Corp refs
(AIAA PAPER 93-0330) Copyright

A new 3D adaptive-grid Euler technique capable of automatically detecting large-error/high-gradient regions in the flow is presented. The technique locally subdivides the computational grid in these regions to provide a uniform, high-level of accuracy over the entire domain. The technique is based on a tunable, semi-structured data system for parallel/vector computing, directional grid-embedding adaptation for efficient resolution of high-gradient flow features, and multiple-grid convergence acceleration over all embedded grid regions and grids coarser than the initial grid. As compared to uniform fine-grid solutions, the current procedure requires from 3 to 100 times less computing time and memory for comparable accuracy depending on the complexity of the flow field. O.G.

A93-23283#
MEASUREMENTS IN A PRESSURE-DRIVEN THREE-DIMENSIONAL TURBULENT BOUNDARY LAYER DURING DEVELOPMENT AND DECAY
WALTER R. SCHWARZ and PETER BRADSHAW (Stanford Univ., CA) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by Boeing Co. and Society of Experimental Test Pilots Scholarship Foundation refs
(AIAA PAPER 93-0543) Copyright

Measurements of the turbulence structure of a three-dimensional turbulent boundary layer (3DTBL) were made in an open-circuit low-speed blower tunnel with a 762 mm x 762 mm working section. The 3DTBL on the floor of the tunnel was generated by the imposition of a cross-stream pressure gradient using a 30 deg bend in the horizontal plane. Downstream of the bend, the 3DTBL gradually relaxed towards a two-dimensional flow as the crossflow decayed slowly after the cross-stream pressure gradient was removed. To a first approximation, the flow was an initial 2DTBL perturbed by a nearly-frozen streamwise vorticity field, which permitted the study of the response and recovery of the turbulence. Author

A93-23333*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DOPPLER GLOBAL VELOCIMETRY MEASUREMENTS OF THE VORTICAL FLOW ABOVE AN F/A-18
JOSEPH W. LEE, JAMES F. MEYERS (NASA, Langley Research Center, Hampton, VA), ANGELO A. CAVONE (Vigyan, Inc., Hampton, VA), and KAREN E. SUZUKI (Joint Inst. for the Advancement of Flight Sciences, Hampton, VA) Jan. 1993 11 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0414) Copyright

A Doppler global velocimeter is employed to study the vortical flow above an F/A-18 at 25 degree angle of attack. The measurements indicate that the flow possessed the same characteristics as the vortical flow above a standard delta wing. Image to image comparisons clearly indicate that the flow striking the vertical stabilizers is not chaotic. R.E.P.

A93-23385#
DIRECT BOUNDARY VALUE SOLUTION OF WAVE ROTOR FLOW FIELDS
WILLIAM E. LEAR, JR. (Florida Univ., Gainesville) and GRAHAM V. CANDLER (Minnesota Univ., Minneapolis) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0483) Copyright

A computational method to analyze the flow in wave rotors and their adjoining ducts has been formulated and implemented. The method solves the flow within the rotor in the absolute frame of reference. The approach rigorously treats of the duct-rotor interface, allowing for the blade-induced work due to an initial non-uniform angle of attack. Several cases were simulated, showing that for off-design conditions the port flows are significantly non-uniform, contrary to conventional models. The calculations also

predict a significant region of recirculation in the high pressure duct. The new computational approach shows promise for further development. Author

A93-23390*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EFFECTS OF FREE-STREAM TURBULENCE ON BOUNDARY-LAYER TRANSITION
TH. HERBERT (Ohio State Univ., Columbus), G. K. STUCKERT, and V. ESFAHANIAN (DynaFlow, Inc., Columbus, OH) Jan. 1993 16 p. AIAA, *Aerospace Sciences Meeting and Exhibit*, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract AF-AFOSR-91-0262; N00014-90-J-1520; NAS3-26602)
(AIAA PAPER 93-0488) Copyright

Traditional methods for the prediction of the transition location rest either on lump parameters like the momentum thickness or on N factors obtained from the approximate linear stability characteristics of the flow. These methods account for the effects of the disturbance environment by empirical correlation with observed transition locations. We have developed a highly efficient and accurate approach to stability analysis and transition simulation based on parabolized stability equations (PSE). Here we present a first application of this approach to realistic problems of practical interest. We study the effects of the turbulence level on transition and heat transfer in flows over flat plates, curved plates, and the stator blade of a gas-turbine model. We discuss the formulation of an input model for the PSE analysis in the light of the present knowledge of receptivity mechanisms. The input model is used to compute transition locations for various configurations and flow conditions. The results compare favorably with experimental data. Author

A93-23477* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYTICAL COMPARISON OF CONVECTIVE HEAT TRANSFER CORRELATIONS IN SUPERCRITICAL HYDROGEN
WILLIAM M. DZIEDZIC, STUART C. JONES (Lockheed Engineering and Sciences Co., Hampton, VA), DANA C. GOULD, and DENNIS H. PETLEY (NASA, Langley Research Center, Hampton, VA) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722) vol. 7, no. 1 Jan.-Mar. 1993 p. 68-73. Previously cited in issue 18, p. 3134, Accession no. A91-43446 refs
Copyright

A93-23491
NUMERICAL STUDY OF MIXED CONVECTION BETWEEN TWO COROTATING SYMMETRICALLY HEATED DISKS
C. Y. SOONG (Chung Cheng Inst. of Technology, Taoyuan, Taiwan) and W. M. YAN (Hua Fan Inst. of Technology, Taipei, Taiwan) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722) vol. 7, no. 1 Jan.-Mar. 1993 p. 165-170. refs
Copyright

This article is concerned with a numerical study of mixed convection between two symmetrically heated corotating disks. Both thermal boundary conditions of constant wall temperature and uniform heat flux are considered. By applying the boundary-layer approximation and a linear relation for density variation in centrifugal force term, the governing equations reduce to a Boussinesq system of parabolic nature. The spatially developing flow and heat transfer are studied numerically. The effects of centrifugal buoyancy, Coriolis force, radial through-flow, and wall-heating on the flow structure and heat transfer performance are examined in detail. The results reveal that the centrifugal buoyancy, which was ignored in prior studies, is indeed a significant effect in this class of rotating flows. Author

A93-23512* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
TIME-VARIANT ANALYSIS OF ROTORCRAFT SYSTEMS DYNAMICS - AN EXPLOITATION OF VECTOR PROCESSORS
F. M. L. AMIROUCHE, M. XIE, and N. H. SHAREEF (Illinois Univ., Chicago) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 1 Jan.-Feb. 1993 p. 96-103. refs
(Contract NAG3-1092)
Copyright

In this paper a generalized algorithmic procedure is presented for handling constraints in mechanical transmissions. The latter are treated as multibody systems of interconnected rigid/flexible bodies. The constraint Jacobian matrices are generated automatically and suitably updated in time, depending on the geometrical and kinematical constraint conditions describing the interconnection between shafts or gears. The type of constraints are classified based on the interconnection of the bodies by assuming that one or more points of contact exist between them. The effects due to elastic deformation of the flexible bodies are included by allowing each body element to undergo small deformations. The procedure is based on recursively formulated Kane's dynamical equations of motion and the finite element method, including the concept of geometrical stiffening effects. The method is implemented on an IBM-3090-600j vector processor with pipe-lining capabilities. A significant increase in the speed of execution is achieved by vectorizing the developed code in computationally intensive areas. An example consisting of two meshing disks rotating at high angular velocity is presented. Applications are intended for the study of the dynamic behavior of helicopter transmissions. Author

A93-23517
DIGITAL SIMULATION OF ATMOSPHERIC TURBULENCE FOR DRYDEN AND VON KARMAN MODELS
T. R. BEAL (E-Systems, Inc., Greenville, TX) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 1 Jan.-Feb. 1993 p. 132-138. refs
Copyright

Algorithms are presented for generating discrete sample time histories of random atmospheric turbulence having statistical characteristics as prescribed by the Dryden and von Karman models defined in MIL-F-8785C. When these algorithms are incorporated into a dynamic simulation, response of an aircraft to the turbulence can be predicted. Such information is useful both in the design stage and during the development phase of the aircraft. The von Karman model is generated using a variation of the sum-of-sinusoids method, modified to reduce computation time. Techniques for improving computational speed are considered, and results of test runs are presented. The Dryden model is generated by passing band-limited white noise through appropriate linear filters. The input variance required to produce the desired output variance is determined as a function of the sample frequency. Generation of roll gust velocities is also addressed, as well as the application of lateral and vertical velocities to the computation of yaw and pitch moments on an aircraft. Author

A93-23547
EDUCTION OF SWIRLING STRUCTURE USING THE VELOCITY GRADIENT TENSOR
C. H. BERDAHL and D. S. THOMPSON (Texas Univ., Arlington) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 97-103. Previously cited in issue 17, p. 2941, Accession no. A91-42610 Research supported by Texas Higher Education Coordinating Board refs
Copyright

A93-23553
MODELING, ANALYSIS, AND PREDICTION OF FLUTTER AT TRANSONIC SPEEDS
K.-Y. FUNG and T. H. SHIEH (Arizona Univ., Tucson) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 140-147. refs
Copyright

The solutions of the two-degree-of-freedom aeroelastic system of an airfoil about different elastic axes are shown to be algebraically homomorphic. A simple aerodynamic model allows the characterization of this system by the lift and moment slopes and two characteristic time constants from the indicial response to pitch, in addition to the usual structural parameters. For flutter

frequencies that are small compared with the characteristic time constants or for time constants that are close in magnitude, these expressions can be further simplified to uncoupled, explicit expressions. It is shown that the flutter speed reaches the minimum (the so-called 'transonic dip') as the slope of pitching (about midchord) moment curve C(m-alpha) becomes maximum. Hence, the Mach number of the transonic dip is predictable using quasi-steady aerodynamics. Examples are also given to show the applicability of this simple criterion for the transonic dip of supercritical wings. Author

A93-23554* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DIRECT SOLUTION OF TWO-DIMENSIONAL NAVIER-STOKES EQUATIONS FOR STATIC AEROELASTICITY PROBLEMS
FORT F. FELKER (NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 148-153. Previously cited in issue 14, p. 2376, Accession no. A92-35691 refs
Copyright

A93-23555* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FINITE ELEMENT NONLINEAR PANEL FLUTTER WITH ARBITRARY TEMPERATURES IN SUPERSONIC FLOW
DAVID Y. XUE and CHUH MEI (Old Dominion Univ., Norfolk, VA) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 154-162. Previously cited in issue 14, p. 2376, Accession no. A92-35696 refs
(Contract NAS1-18584)
Copyright

A93-23557* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLEXURE-TORSION BEHAVIOR OF PRISMATIC BEAMS. I - SECTION PROPERTIES VIA POWER SERIES
J. B. KOSMATKA (California Univ., La Jolla) AIAA Journal (ISSN 0001-1452) vol. 31, no. 1 Jan. 1993 p. 170-179. refs
(Contract NAG1-1151)
Copyright

The behavior of a tip-loaded cantilever beam with an arbitrary cross section is studied using Saint-Venant's semi-inverse method along with a power series solution for the out-of-plane flexure and torsion warping functions. The power series coefficients are determined by solving a set of variationally derived linear algebraic equations. For complex cross sections, the calculated coefficients represented a 'best-fit approximation' to the exact warping function. The resulting warping functions are used to determine the cross-sectional properties (torsion constant, shear correction factors, shear deformation coefficients, and shear center location). A new linear relation is developed for locating the shear center, where the twist rate is zero about the line of shear centers. Moreover, the kinematic relations for a new fully compatible one-dimensional beam theory are developed. Numerical results are presented first to verify the approach and second to provide section data on NACA four-series airfoils not currently found in the literature. Author

N93-15698# Federal Aviation Administration, Atlantic City, NJ.
FAA TECHNICAL CENTER AERONAUTICAL DATA LINK RESEARCH PLAN Final Report, Oct. 1991 - Sep. 1992
FRANK BUCK (Mitre Corp., Baileys Crossroads, VA.), PRESTON CRATCH (Mitre Corp., Baileys Crossroads, VA.), TERENCE FISCHER (Computer Technology Associates, Inc., Arlington, VA.), JOSEPH LUNDER (TMA Technologies, Inc., Bozeman, MT.), CLARK SHINGLEDECKER (NTI, Inc., Dayton, OH.), DAVID STAHL (Computer Technology Associates, Inc., Arlington, VA.), and DAVID SWEENEY (Mitre Corp., Baileys Crossroads, VA.) Oct. 1992 60 p
(Contract FAA-F2205-A)
(DOT/FAA/CT-92/23) Avail: CASI HC A04/MF A01

The purpose of this plan is to project a clear and distinct description of the Data Link research that is to be conducted at the Federal Aviation Administration (FAA) Technical Center over the next 4 years. It explicitly defines what is to be achieved at a specific time in the future. End-to-end, high fidelity simulations will be the primary methodology for answering research questions. The end-to-end simulations identified in this plan are intended to investigate controller/aircrew integration issues using candidate Data Link hardware and software configurations. Research will also focus on testing Data Link applications in terms of their impact on controllers, aircrew, and the overall safety, efficiency, and productivity of the system. Additionally, research efforts are planned to address the most critical human factors issues surrounding Data Link. Author

N93-15801*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
BYPASS TRANSITION IN COMPRESSIBLE BOUNDARY LAYERS
J. J. VANDERVEGT *In its* Center for Modeling of Turbulence and Transition (CMOTT): Research Briefs, 1992 p 115-125 Sep. 1992
Avail: CASI HC A03/MF A02

Transition to turbulence in aerospace applications usually occurs in a strongly disturbed environment. For instance, the effects of free-stream turbulence, roughness and obstacles in the boundary layer strongly influence transition. Proper understanding of the mechanisms leading to transition is crucial in the design of aircraft wings and gas turbine blades, because lift, drag and heat transfer strongly depend on the state of the boundary layer, laminar or turbulent. Unfortunately, most of the transition research, both theoretical and experimental, has focused on natural transition. Many practical flows, however, defy any theoretical analysis and are extremely difficult to measure. Morkovin introduced in his review paper the concept of bypass transition as those forms of transition which bypass the known mechanisms of linear and non-linear transition theories and are currently not understood by experiments. In an effort to better understand the mechanisms leading to transition in a disturbed environment, experiments are conducted studying simpler cases, viz. the effects of free stream turbulence on transition on a flat plate. It turns out that these experiments are very difficult to conduct, because generation of free stream turbulence with sufficiently high fluctuation levels and reasonable homogeneity is non trivial. For a discussion see Morkovin. Serious problems also appear due to the fact that at high Reynolds numbers the boundary layers are very thin, especially in the nose region of the plate where the transition occurs, which makes the use of very small probes necessary. The effects of free-stream turbulence on transition are the subject of this research and are especially important in a gas turbine environment, where turbulence intensities are measured between 5 and 20 percent, Wang et al. Due to the fact that the Reynolds number for turbine blades is considerably lower than for aircraft wings, generally a larger portion of the blade will be in a laminar transitional state. The effects of large free stream turbulence in compressible boundary layers at Mach numbers are examined both in the subsonic and transonic regime using direct numerical simulations. The flow is computed over a flat plate and curved surface. while many applications operate in the transonic regime. Due the nature of their numerical scheme, a non-conservation formulation of the Navier-Stokes equations, it is a non-trivial extension to compute flow fields in the transonic regime. This project aims at better understanding the effects of large free-stream turbulence in compressible boundary layers at mach number both in the subsonic and transonic regime using direct numerical simulations. The present project aims at computing the flow over a flat plate and curved surface. This research will provide data which can be used to clarify mechanisms leading to transition in an environment with high free stream turbulence. This information is useful for the development of turbulence models, which are of great importance for CFD applications, and are currently unreliable for more complex flows, such as transitional flows. Author

N93-15857# Naval Surface Warfare Center, Dahlgren, VA.
DETAILED NEAR SURFACE FLOW ABOUT YAWED, STRANDED CABLES Report, May 1989 - Jun. 1990
S. M. BATILL and J. V. NEBRES Oct. 1992 146 p
(Contract N00014-83-K-0239; NR PROJ. RN1-5-W-33)
(AD-A257382; CSS-CR-1210-92-1) Avail: CASI HC A07/MF A02

The results are described of the second phase of an experimental study of the flow about stranded cables or wire ropes. The purpose was to consider, in some detail, the flow field near the cable and to provide additional experimental information related to the mechanisms associated with the generation of fluid forces on the cables. The development of a steady lift or side force on a stranded cable, yawed with respect to a flow, is a unique characteristic of a cable when compared to a circular cylinder. Experiments were conducted to measure the surface pressure distributions and near wake characteristics for a variety of stranded cable geometries and a circular cylinder. Rigid cable models and cylinders were tested in a low speed wind tunnel. The models were yawed to four different yaw angles and tested within the Reynolds number range of 5,000 and 50,000. Surface pressure distributions on the yawed cables indicated that the lift force is the result of asymmetric boundary layer separation. Unsteady surface pressures on stationary cables were shown to correlate with earlier hot-wire measurements. Detailed flow visualization illustrated the complexity of the flow about the stranded cables. The influence of test support conditions were examined in order to provide a better understanding of end-effects in testing these long, slender models. GRA

N93-16379*# Vigyan Research Associates, Inc., Hampton, VA.
MODELING AND CONTROL STUDY OF THE NASA 0.3-METER TRANSONIC CRYOGENIC TUNNEL FOR USE WITH SULFUR HEXAFLUORIDE MEDIUM
S. BALAKRISHNA and W. ALLEN KILGORE Dec. 1992 62 p
(Contract NAS1-18585; RTOP 505-59-86-02)
(NASA-CR-189737; NAS 1.26:189737) Avail: CASI HC A04/MF A01

The NASA Langley 0.3-m Transonic Cryogenic Tunnel is to be modified to operate with sulfur hexafluoride gas while retaining its present capability to operate with nitrogen. The modified tunnel will provide high Reynolds number flow on aerodynamic models with two different test gases. The document details a study of the SF6 tunnel performance boundaries, thermodynamic modeling of the tunnel process, nonlinear dynamical simulation of math model to yield tunnel responses, the closed loop control requirements, control laws, and mechanization of the control laws on the microprocessor based controller. Author

N93-16411# National Aerospace Lab., Amsterdam (Netherlands). Fluid Dynamics Div.
COMPARISON OF SOLUTION OF VARIOUS EULER SOLVERS AND ONE NAVIER-STOKES SOLVER FOR THE FLOW ABOUT A SHARP-EDGED CROPPED DELTA WING
B. R. WILLIAMS (Royal Aerospace Establishment, Farnborough, England), W. KORDULLA (Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen, Germany), M. BORSI (Aeritalia S.p.A., Turin, Italy), and H. W. M. HOEIJMAKERS 28 Aug. 1990 17 p Presented at AGARD Dynamics Symposium on Vortex Flow Aerodynamics, Scheveningen, Netherlands, 1-4 Oct. 1990 Sponsored by Netherlands Agency for Aerospace Programs
(NLR-TP-90340-U; ETN-93-92863) Avail: CASI HC A03/MF A01

The flow about a sharp edged cropped 65 deg delta wing was calculated. Numerical solutions obtained with different Euler methods are compared with each other, with the numerical solution of a Reynolds averaged Navier-Stokes method and with experimental data. At the selected free stream Mach number of 0.85 and angle of attack of 10 deg the flow features a leading edge vortex, is transonic but contains weak shocks only. The results of the Euler methods were obtained on one and the same C-H type of grid with close to 300,000 cells. The investigation indicates that for the test case considered there are significant differences between results from different Euler methods. The correlation of the Euler solutions with experimental data shows much larger differences due to the failure to represent secondary separation in the Euler methods. The results of the Reynolds averaged Navier-Stokes method demonstrate an improved correlation of theory and experiment. ESA

N93-16543# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany). Hauptabt. Windkanaele.
ON FLUTTER BEHAVIOR OF A 2-D COMPRESSOR CASCADE IN INCOMPRESSIBLE FLOW Ph.D. Thesis - Technische Hochschule [ZUM FLATTERVERHALTEN EINES 2-D VERDICHTERGITTERS IN INKOMPRESSIBLER STROEMUNG]
WERNER SACHS Sep. 1991 128 p In GERMAN
(ISSN 0939-2963)
(DLR-FB-91-26; ETN-93-92397) Avail: CASI HC A07/MF A02; DLR, Wissenschaftliches Berichtswesen, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Germany, HC

Investigations on unsteady aerodynamics and flutter behavior of a compressor cascade in a newly developed wind tunnel for incompressible flow are described. Several new details of the design of the wind tunnel, the measurement section, the data processing system, and the computer supported measurement control system, are presented. The results of the extensive systematic measurements of unsteady pressure distributions on the constrained excited cascade are described and discussed. Investigations of flutter stability and additional flutter cases are presented. ESA

N93-16558*# Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics.
VOLUME 2: EXPLICIT, MULTISTAGE UPWIND SCHEMES FOR EULER AND NAVIER-STOKES EQUATIONS Final Report, period ending 15 Sep. 1992
ALAA ELMILIGUI and ROBERT L. ASH Dec. 1992 214 p
(Contract NAG1-633)
(NASA-CR-191647; NAS 1.26:191647) Avail: CASI HC A10/MF A03

The objective of this study was to develop a high-resolution-explicit-multi-block numerical algorithm, suitable for efficient computation of the three-dimensional, time-dependent Euler and Navier-Stokes equations. The resulting algorithm has employed a finite volume approach, using monotonic upstream schemes for conservation laws (MUSCL)-type differencing to obtain state variables at cell interface. Variable interpolations were written in the k-scheme formulation. Inviscid fluxes were calculated via Roe's flux-difference splitting, and van Leer's flux-vector splitting techniques, which are considered state of the art. The viscous terms were discretized using a second-order, central-difference operator. Two classes of explicit time integration has been investigated for solving the compressible inviscid/viscous flow problems--two-state predictor-corrector schemes, and multistage time-stepping schemes. The coefficients of the multistage time-stepping schemes have been modified successfully to achieve better performance with upwind differencing. A technique was developed to optimize the coefficients for good high-frequency damping at relatively high CFL numbers. Local time-stepping, implicit residual smoothing, and multigrid procedure were added to the explicit time stepping scheme to accelerate convergence to steady-state. The developed algorithm was implemented successfully in a multi-block code, which provides complete topological and geometric flexibility. The only requirement is C degree continuity of the grid across the block interface. The algorithm has been validated on a diverse set of three-dimensional test cases of increasing complexity. The cases studied were: (1) supersonic corner flow; (2) supersonic plume flow; (3) laminar and turbulent flow over a flat plate; (4) transonic flow over an ONERA M6 wing; and (5) unsteady flow of a compressible jet impinging on a ground plane (with and without cross flow). The emphasis of the test cases was validation of code, and assessment of performance, as well as demonstration of flexibility. Author

N93-16786*# Alabama Univ., Tuscaloosa. Dept. of Mechanical Engineering.

COMPARISON OF METHODOLOGIES FOR DESCRIBING RELAXATION IN NONEQUILIBRIUM GASEOUS SYSTEMS

WILLARD C. SCHREIBER *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 169-170 Sep. 1992

Avail: CASI HC A01/MF A03

The heat transfer process in hypervelocity vehicles is dominated by nonequilibrium gas dynamics. One model used in computational fluid dynamics (CFD) codes to predict hypervelocity heat transfer is the 'two-temperature' model. An analysis has been made to test the validity of the two-temperature model for predicting another nonequilibrium phenomenon, sound absorption and deviation of signal speed in a high temperature gas. It is found that the two temperature model's prediction capabilities degenerate with increasing temperature. These results are felt to have significance concerning the two-temperature's ability to predict heat transfer in hypervelocity flows. Author

N93-16793*# Washington Univ., Saint Louis, MO. Dept. of Civil Engineering.

MODE INTERACTION IN STIFFENED COMPOSITE SHELLS UNDER COMBINED MECHANICAL AND THERMAL LOADINGS

SRINIVASAN SRIDHARAN *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 183-184 Sep. 1992

Avail: CASI HC A01/MF A03

Stiffened shells of various configurations fabricated out of composite materials find extensive applications in aircraft structures. Two distinctive modes of buckling dominate structural response of stiffened panels, viz. the short-wave local mode in which the shell skin buckles essentially between the stiffeners and the long-wave overall mode in which the shell skin buckles carrying the stiffeners with it. In optimized designs, the critical stresses corresponding to these modes of buckling would be close to each other. This leads to a nonlinear mode interaction which is recognized to be the principal cause of the failure of stiffened structures. If the structure is subjected to through-the-thickness thermal gradients, then large-wave bending effects would begin to occur well below the overall critical load and these would play the role of overall imperfections. The load carrying capacity would be significantly diminished as a result of interaction of local buckling with overall thermal distortions. The analysis of this problem using standard finite element techniques can be shown to be prohibitively expensive for design iterations. A concept which would greatly facilitate the analysis of mode interaction is advanced. We note that the local buckling occurs in a more or less periodic pattern in a structure having regular spacings of stiffeners. Thus it is a relatively simple matter to analyze the local buckling and the second order effects (which are essential for modeling postbuckling phenomena) using a unit cell of the structure. Once analyzed, these dormations are embedded in a shell element. Thus, a shell element could span several half-waves of local buckling and still be able to depict local buckling effects with requisite accuracy. A major consequence of the interaction of overall buckling/bending is the slow variation of the local buckling amplitude across the structure - the phenomenon of 'amplitude modulation' - and this is accounted for in the present model by letting the scaling parameter of the local mode vary according to a 'slowly varying' function. The construction of the analytical model involves essentially two stages and these are described briefly. Author

N93-16818# Tohoku Univ., Sendai (Japan). Faculty of Engineering.

THREE DIMENSIONAL BOUNDARY-LAYER TRANSITION ON A SWEPT WING [KOUTAIYOKU MAWARI NO SANJIGEN KYOUKAISOU SENI]

YASUAKI KOHAMA *In* NAL, Proceedings of the 7th and 8th NAL Workshops on Investigation and Control of Boundary-Layer Transition p 39-42 Sep. 1991 In JAPANESE

Avail: CASI HC A01/MF A01

Stability and transition experiments are conducted on a 45 deg swept airfoil in the Arizona State University (ASU) Unsteady Wind Tunnel. The pressure gradient is designed to obtain pure cross flow dominated transition where the instability occurs through cross flow vortices that are generic to three dimensional boundary layers. Flow visualization and hot-wires are used to show that transition to turbulence occurs through a high frequency, secondary instability that appears when the streamwise velocity profile is distorted by the stationary cross flow vortex. Multiple inflection points occur in the velocity profiles in very localized regions. These regions, characterized by spanwise velocity gradients that are the same magnitude as the normal to the wall gradients, are the source of the sawtooth transition patterns. The traveling cross flow waves, although strongly amplified, appear to play only a passive role in the transition process. Detailed roughness measurements near the attachment line account for the strongly three dimensional transition patterns that have been observed. Author (NASDA)

N93-16829# National Aerospace Lab., Tokyo (Japan).

EXPERIMENTS ON SWEPT-WING BOUNDARY-LAYER TRANSITION [KOUTAIYOKU NI SOU SANJIGEN KYOUKAISOU SENI NI TSUITE]

SHOUHEI TAKAGI and W. S. SARIC *In its* Proceedings of the 7th and 8th NAL Workshops on Investigation and Control of Boundary-Layer Transition p 89-91 Sep. 1991 In JAPANESE

Avail: CASI HC A01/MF A01

The three dimensional boundary layer experiments were conducted on a 45 deg swept wing in the Arizona State University (ASU) unsteady wind tunnel. Cross flow dominated transition was produced on a very smooth surface with contoured end liners to simulate infinite swept wing flow. The model surface was carefully polished and buffed up to plus or minus 3 micrometer to minimize roughness effects on transition. Fixed wavelength vortices, traveling wave and inflectional breakdown were subsequently observed prior to turbulent state as before, but the transition location moved further 10 percent to 20 percent downstream of the chord length. In order to control traveling wave and inflectional breakdown, two kinds of acoustic sounds, which tune up the traveling wave and breakdown, respectively, were introduced visualizing the surface flow via two or three dimensional roughness elements. No acoustic effect was observed in visualization. Author (NASDA)

N93-17289*# Carnegie-Mellon Univ., Pittsburgh, PA. Dept. of Mechanical Engineering.

CFD ANALYSIS ON CONTROL OF SECONDARY LOSSES IN STME LOX TURBINES WITH ENDWALL FENCES

MINGKING K. CHYU *In* Alabama Univ., 1992 NASA/ASEE Summer Faculty Fellowship Program 5 p Dec. 1992

Avail: CASI HC A01/MF A03

The rotor blade in the newly designed LOX turbine for the future Space Transportation Main Engine (STME) has a severe flow turning angle, nearly 160 degrees. The estimated secondary loss in the rotor alone accounts for nearly 50 percent of the total loss over the entire stage. To reduce such a loss, one of the potential methods is to use fences attached on the turbine endwall (hub). As a prelude to examining the effects of endwall fence with actual STME turbine configuration, the present study focuses on similar issues with a different, but more generic, geometry - a rectangular duct with a 160-degree bend. The duct cross-section has a 2-to-1 aspect ratio and the radii of curvature for the inner and outer wall are 0.25 and 1.25 times the duct width, respectively. The present emphasis lies in examining the effects of various fence-length extending along the streamwise direction. The flowfield is numerically simulated using the FDNS code developed earlier by Wang and Chen. The FDNS code is a pressure based, finite-difference, Navier-Stokes equations solver. I.I.C.

N93-17761# Clarkson Univ., Potsdam, NY. Dept. of Chemical Engineering.

LIFT AND DRAG FORCES ON DROPLETS AND PARTICLES IN WALL-BOUNDED SHEAR FLOWS

J. B. MCLAUGHLIN 1992 10 p

(Contract DE-FG02-88ER-13919)
(DE93-002678; DOE/ER-13919/5) Avail: CASI HC A02/MF A01
This project has two goals: to calculate the lift force on a spherical droplet or particle that translates through a shear flow; and to measure the inertial migration velocity that is caused by the lift force. The focus of the study is on a range of Reynolds numbers that has been shown to be of importance in the inertial deposition of aerosols from turbulent shear flows. Aspects of current technical progress summarized are the asymptotic analysis, computer simulations, and experimental measurements. Future plans and resulting publications are given. DOE

N93-17779*# *National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.*
TRANSIENT/STRUCTURAL ANALYSIS OF A COMBUSTOR UNDER EXPLOSIVE LOADS
PEYTON B. GREGORY and ANNE D. HOLLAND Dec. 1992 27 p
(Contract RTOP 505-43-31-05)
(NASA-TM-107660; NAS 1.26:107660) Avail: CASI HC A03/MF A01
The 8-Foot High Temperature Tunnel (HTT) at NASA Langley Research Center is a combustion-driven blow-down wind tunnel. A major potential failure mode that was considered during the combustor redesign was the possibility of a deflagration and/or detonation in the combustor. If a main burner flame-out were to occur, then unburned fuel gases could accumulate and, if reignited, an explosion could occur. An analysis has been performed to determine the safe operating limits of the combustor under transient explosive loads. The failure criteria was defined and the failure mechanisms were determined for both peak pressures and differential pressure loadings. An overview of the gas dynamics analysis was given. A finite element model was constructed to evaluate 13 transient load cases. The sensitivity of the structure to the frequency content of the transient loading was assessed. In addition, two closed form dynamic analyses were conducted to verify the finite element analysis. It was determined that the differential pressure load or thrust load was the critical load mechanism and that the nozzle is the weak link in the combustor system. Author

N93-18047*# Minnesota Univ., Minneapolis. Dept. of Aerospace Engineering and Mechanics.
CONCEPTUAL DESIGN OF A MARS TRANSPORTATION SYSTEM Final Design Report
11 Aug. 1992 165 p
(Contract NASW-4435)
(NASA-CR-192039; NAS 1.26:192039) Avail: CASI HC A08/MF A02
In conjunction with NASA Marshall Space Flight Center and several major aerospace corporations the University of Minnesota has developed a scenario to place humans on Mars by the year 2016. The project took the form of a year-long design course in the senior design curricula at the University's Aerospace Engineering and Mechanics Department. Students worked with the instructor, teaching assistants and engineers in industry to develop a vehicle and the associated mission profile to fulfill the requirements of the Mars Transportation System. This report is a summary of the final design and the process though which the final product was developed. Author

N93-18093*# Computational Mechanics Co., Austin, TX.
H-P ADAPTIVE METHODS FOR FINITE ELEMENT ANALYSIS OF AEROTHERMAL LOADS IN HIGH-SPEED FLOWS
H. J. CHANG, J. M. BASS, W. TWORZYDLO, and J. T. ODEN Jan. 1993 290 p
(Contract NAS1-18746; RTOP 506-40-21)
(NASA-CR-189739; TR-92-12; NAS 1.26:189739) Avail: CASI HC A13/MF A03
The commitment to develop the National Aerospace Plane and Maneuvering Reentry Vehicles has generated resurgent interest in the technology required to design structures for hypersonic flight. The principal objective of this research and development effort has been to formulate and implement a new class of computational methodologies for accurately predicting fine scale phenomena associated with this class of problems. The initial focus of this effort was to develop optimal h-refinement and p-enrichment adaptive finite element methods which utilize a-posteriori estimates of the local errors to drive the adaptive methodology. Over the past year this work has specifically focused on two issues which are related to overall performance of a flow solver. These issues include the formulation and implementation (in two dimensions) of an implicit/explicit flow solver compatible with the hp-adaptive methodology, and the design and implementation of computational algorithm for automatically selecting optimal directions in which to enrich the mesh. These concepts and algorithms have been implemented in a two-dimensional finite element code and used to solve three hypersonic flow benchmark problems (Holden Mach 14.1, Edney shock on shock interaction Mach 8.03, and the viscous backstep Mach 4.08). Author

N93-18103# Manchester Univ. (England). Aeronautical Engineering Group.
MODELLING OF INTERFACIAL AND THERMOCLINE WAVES Quarterly Progress Report No. 5
D. NICOLAOU, F. A. PAONESSA, and T. N. STEVENSON 1992 12 p Sponsored by Ministry of Defence
(AERO-REPT-9209; ETN-93-93009) Avail: CASI HC A03/MF A01
Progress of the theory and of experimental work is given. A program for a body moving in an enclosed region surrounded by solid walls was completed. Finite difference results obtained from this program can be used to compare with experimental results of thermocline waves. Numerical investigations surrounding the implementation of open boundary conditions in the present finite difference program are considered. In the experimental investigation, preliminary runs towing the boat model to investigate its drag characteristics in different thermocline thicknesses are considered. The model was first towed in a tank of freshwater to give a baseline for the drag variation with speed. A graph of drag against speed for varying model configurations is given. The variation of drag with speed for different thermocline thicknesses is shown as the interface was allowed to diffuse with time. ESA

N93-18121# Pennsylvania State Univ., University Park. Applied Research Lab.
EXPERIMENTAL ANALYSIS OF THE AEROACOUSTICS OF CASCADED AIRFOILS
L. A. PERRY and G. C. LAUCHLE Nov. 1992 99 p
(AD-A257945; PSU/ARL-TR-92-08) Avail: CASI HC A05/MF A02
The purpose of this study is to investigate the noise radiated by various louver designs. A louver is essentially a cascade of small airfoils, operating at the same angle of attack. Louvers are commonly used in heating, ventilation, and air conditioning (HVAC) systems to provide directional control of the exit airflow. The HVAC system of an automobile can be a significant source of acoustic annoyance. Louvers are typically placed in the near field of the driver and passenger and can be major contributors to the overall interior noise level. In this study, thirteen representative dashboard registers used in automotive HVAC applications are considered. These registers vary in airfoil shape, number of airfoils, number of support struts, inlet and outlet sizes, and other physical parameters. The research documented in this thesis is directed toward a better understanding of the parameters that significantly affect the amount of noise generated by a louver. GRA

N93-18305# *Naval Postgraduate School, Monterey, CA.*
NUMERICAL ANALYSIS OF THE FLOW IN A TURBULATED RECTANGULAR DUCT SIMULATING THE COOLING PASSAGES IN A TURBINE BLADE M.S. Thesis
ROBERT M. PALATKA 15 Jun. 1992 93 p
(AD-A257855) Avail: CASI HC A05/MF A01
An extensive review of the literature revealed that many experimental studies have been conducted in heat-transfer wind

tunnels simulating the cooling passages in turbine blades. However, very few numerical studies have been performed. Phoenics, a computational fluid dynamics computer program, produced results for several duct configurations and calculated the heat transfer characteristics of each. The configurations investigated included a straight, square duct and a rectangular duct with turbulators, (a form of turbulence promoter) present. The parameters varied included Reynolds number, turbulence intensity, and grid geometry. Results for the turbulated duct indicated highly distinct and repeatable flow patterns developed over a wide range of values. The variation of the inlet turbulence intensity had little impact on the kinetic energy. The results proved to be highly grid dependent, which greatly impacted the correlation between experimentally and numerically produced data, for the same configurations, under similar operating parameters. GRA

N93-18321*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
BRUSH SEAL BRISTLE FLEXURE AND HARD-RUB CHARACTERISTICS
ROBERT C. HENDRICKS, JULIE A. CARLILE, and ANITA D. LIANG Aug. 1992 23 p Presented at the Seals Workshop, Cleveland, OH, 5-6 Aug. 1992
(Contract RTOP 590-21-11)
(NASA-TM-105864; E-7281; NAS 1.15:105864) Avail: CASI HC A03/MF A01

The bristles of a 38.1-mm (1.5-in) diameter brush seal were flexed by a tapered, 40-tooth rotor operating at 2600 rpm that provided sharp leading-edge impact of the bristles with hard rubbing of the rotor lands. Three separate tests were run with the same brush accumulating over 1.3 x 10(exp 9) flexure cycles while deteriorating 0.2 mm (0.008 in) radially. In each, the test bristle incursion depth varied from 0.130 to 0.025 mm (0.005 to 0.001 in) or less (start to stop), and in the third test the rotor was set 0.25 mm (0.010 in) eccentric. Runout varied from 0.025 to 0.076 mm (0.001 to 0.003 in) radially. The bristles wore but did not pull out, fracture, or fragment. Bristle and rotor wear debris were deposited as very fine, nearly amorphous, highly porous materials at the rotor groove leading edges and within the rotor grooves. The land leading edges showed irregular wear and the beginning of a convergent groove that exhibited sharp, detailed wear at the land trailing edges. Surface grooving, burnishing, 'whipping,' and hot spots and streaks were found. With a smooth-plug rotor post-test leakage increased 30 percent over pretest leakage. Author

N93-18380*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INTEGRITY TESTING OF BRUSH SEAL IN SHROUD RING OF T-700 ENGINE
ROBERT C. HENDRICKS, THOMAS A. GRIFFIN, GEORGE B. BOBULA, ROBERT C. BILL, and HAROLD W. HOWE (Technetics, Inc., DeLand, FL.) Aug. 1992 25 p Presented at the Seals Workshop, Cleveland, OH, 5-6 Aug. 1992
(Contract RTOP 590-21-11)
(NASA-TM-105863; E-7282; NAS 1.15:105863) Avail: CASI HC A03/MF A01

A split-ring brush seal was fabricated, installed between two labyrinth-honeycomb shroud seals, and tested in the fourth-stage turbine of a T-700 engine. The annealed Haynes 25 bristles rubbed directly against the nonconditioned, irregular Rene 80 turbine blade shroud surface. A total of 30 hr of cyclic and steady-state data were taken with surface speeds to 335 m/s (1100 ft/s) and shroud temperatures to 620 C (1150 F). Wear appeared to be rapid initially, with an orange flash of hot brush fragments during the first engine startup, to minimal after 10 hr of operation. The brush survived the testing but experienced some bristle pullouts and severe bristle wear; some turbine interface wear and possible material transfer was noted. Future design concerns center on tribological behavior at the interface with or without lubricants. Author

N93-18426*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DYNAMICS OF ROTATING MULTI-COMPONENT TURBOMACHINERY SYSTEMS
CHARLES LAWRENCE Jan. 1993 14 p Presented at the 34th Structures, Structural Dynamics, Materials Conference, La Jolla, CA, 19-21 Apr. 1993; sponsored by AIAA
(Contract RTOP 505-63-53)
(NASA-TM-105997; E-7537; NAS 1.15:105997) Avail: CASI HC A03/MF A01

The ultimate objective of turbomachinery vibration analysis is to predict both the overall, as well as component dynamic response. To accomplish this objective requires complete engine structural models, including multistages of bladed disk assemblies, flexible rotor shafts and bearings, and engine support structures and casings. In the present approach each component is analyzed as a separate structure and boundary information is exchanged at the inter-component connections. The advantage of this tactic is that even though readily available detailed component models are utilized, accurate and comprehensive system response information may be obtained. Sample problems, which include a fixed base rotating blade and a blade on a flexible rotor, are presented. Author

N93-18563# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
COMPUTATIONAL FLUID DYNAMICS, VOLUME 2
1992 265 p Lecture series held in Rhode-Saint-Genese, Belgium, 23-27 Mar. 1992
(ISSN 0377-8312)
(VKI-LS-1992-04-VOL-2; ETN-92-92362) Copyright Avail: CASI HC A12/MF A03

Three papers are presented. The following topics are discussed: the validation of central and upwind three dimensional compressible flow solvers; the development and numerical solution of Parabolized Navier-Stokes (PNS) equations; and the development of a streamwise upwind algorithm for appliciation to aerodynamics and aeroelasticity. ESA

N93-18564# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
VALIDATION OF CENTRAL AND UPWIND 3D COMPRESSIBLE FLOW SOLVERS
M. MANNA *In its* Computational Fluid Dynamics, Volume 2 62 p 1992
Copyright Avail: CASI HC A04/MF A03

The difficult task of choosing a numerical method that can accurately and efficiently solve Euler equations is discussed while remaining aware of the fact that the practical importance of Euler equations in the context of real flows is limited, although not negligible. Emphasis is given to techniques which can properly handle the strong discontinuities (shock waves and contact discontinuities) typical of high speed flows. Different numerical methods (central and upwind) are compared on the basis of well defined test cases. Performances of the 'state of art' algorithms which can presently be used and coded for real engineering applications are evaluated. Fundamental work in algorithm development, which is inspired by the limitations of the available methods, is discussed and preliminary results on standard two dimensional (2D) test cases are presented. A detailed comparison of numerical results obtained for two test cases in delta wing geometries is presented. A comparison between computations with independently developed upwind Euler solvers are presented using identical grids. Several published results by other authors, based on both upwind and central discretization, are also compared. ESA

N93-18565*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
PARABOLIZED NAVIER-STOKES METHODS FOR HYPERSONIC FLOWS

S. L. LAWRENCE *In* VKI, Computational Fluid Dynamics, Volume 2 114 p 1992
Copyright Avail: CASI HC A06/MF A03

The development and numerical solution of the Parabolized Navier-Stokes (PNS) equations is discussed. Special emphasis is placed on numerical integration algorithms for PNS solvers, most notably recent applications of upwind schemes. Application of this technology to high speed, high Reynolds number flows was the focus, and modeling techniques for real gas effects and turbulence were discussed. Experiences in validating the UPS upwind PNS flow solver for relatively simple body shapes are presented. The test cases range in complexity from two dimensional perfect gas cases to three dimensional finite rate chemistry cases. ESA

N93-18566*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ALGORITHM DEVELOPMENT WITH APPLICATIONS TO AERODYNAMICS AND AEROELASTICITY
P. M. GOORJIAN, S. OBAYASHI, N. M. CHADERJIAN, and G. P. GURUSWAMY *In* VKI, Computational Fluid Dynamics, Volume 2 81 p 1992
Copyright Avail: CASI HC A05/MF A03

The development of a streamwise upwind algorithm is presented. Applications of this algorithm to steady flow over a delta wing and unsteady flow over an oscillating wing, respectively, are covered. An extension to higher order accuracy for upwind methods is discussed. This scheme will use the compatibility relations for the extension. The use of multiple zones in the calculation of unsteady flows is considered. Multiple zones are one way to treat complex configurations, such as complete aircraft. Aeroelastic calculations are discussed. A procedure for aeroelastic calculations is described that simultaneously solves the aerodynamic and structural equations of motion. Sample calculations are given to illustrate the above. ESA

N93-18576*# Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.
BASIC RESEARCH ON DESIGN ANALYSIS METHODS FOR ROTORCRAFT VIBRATIONS Semiannual Progress Report, 21 Jun. - 20 Dec. 1991
S. HANAGUD Dec. 1991 24 p
(Contract NAG1-1007)
(NASA-CR-191917; NAS 1.26:191917) Avail: CASI HC A03/MF A01

The objective of the present work was to develop a method for identifying physically plausible finite element system models of airframe structures from test data. The assumed models were based on linear elastic behavior with general (nonproportional) damping. Physical plausibility of the identified system matrices was insured by restricting the identification process to designated physical parameters only and not simply to the elements of the system matrices themselves. For example, in a large finite element model the identified parameters might be restricted to the moduli for each of the different materials used in the structure. In the case of damping, a restricted set of damping values might be assigned to finite elements based on the material type and on the fabrication processes used. In this case, different damping values might be associated with riveted, bolted and bonded elements. The method itself is developed first, and several approaches are outlined for computing the identified parameter values. The method is applied first to a simple structure for which the 'measured' response is actually synthesized from an assumed model. Both stiffness and damping parameter values are accurately identified. The true test, however, is the application to a full-scale airframe structure. In this case, a NASTRAN model and actual measured modal parameters formed the basis for the identification of a restricted set of physically plausible stiffness and damping parameters. Author

N93-18623# Institut National de Recherche d'Informatique et d'Automatique, Le Chesnay (France). Programme 6: Calcul Scientifique, Modelisation et Logiciels Numeriques.
EXACT-GRADIENT SHAPE OPTIMIZATION OF A 2D EULER FLOW [OPTIMISATION DE PROFILS PAR UNE METHODE DE GRADIENT EXACT POUR UN ECOULEMENT 2D EULERIEN]
FRANCOIS BEUX and ALAIN DERVIEUX Oct. 1991 34 p
(Contract BRITE/EURAM-1082) (ISSN 0249-6399)
(INRIA-RR-1540; ETN-93-92662) Avail: CASI HC A03/MF A01

The optimization of an obstacle shape put into a 2D (two dimensional) Euler flow is addressed. In order to apply a descent method, the differentiation of the flow solution is considered with respect to the shape. In the continuous case, the derivatives (Hadamard variational formula) are formally constructed. In the discrete case, an upwind method with flux splitting is chosen, and an exact gradient is proved to be computable using adjoint state. The behavior of a gradient method is studied for a family of nozzle flows. ESA

N93-18721# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
AXIAL FLOW COMPRESSORS, VOLUME 1
1992 435 p Lecture series held in Rhode-Saint-Genese, Belgium, 27-31 Jan. 1992
(ISSN 0377-8312)
(VKI-LS-1992-02-VOL-1; ETN-92-92164) Avail: CASI HC A19/MF A04

Lectures mainly concentrating on the rotating stall aspect of the unsteady flow, and to a lesser extent on the new features in the blade design, are presented. Fundamental flow behavior and detailed structures of the stall pattern were discussed, using laboratory experiments. The full scale problems were addressed in the lectures on the experiments and analytical studies made on engine compressors. The flow imposed upon a compressor by the inlet was described in an introductory lecture to situate the problem. The description and inception of stall, with ideas about active control, started the lectures on stall related problems. It is expected that compressors can be operated closer to the stall line by monitoring the signs of an imminent stall and taking appropriate action. Laboratory models were discussed using single and multistage configurations, with a comparison to engine type compressor behavior.

ESA

N93-18722# Rolls-Royce Ltd., Derby (England). Compressor Engineering Dept.
THE EFFECT OF AIRCRAFT INLETS ON THE BEHAVIOUR OF AERO ENGINE AXIAL FLOW COMPRESSORS
CHRISTOPHER J. FREEMAN *In* VKI, Axial Flow Compressors, Volume 1 31 p 1992
Avail: CASI HC A03/MF A04

The air inlet and its effect on turbocompressors are described, covering the following: the engine aircraft operating envelopes, inlet loading, interaction between inlet and compressor, compression distortion tolerance, response of compressor to inlet total pressure distortion, inlet and outlet static pressure distribution, and other threats to compressor stability due to inlet. The following conclusions are made: the aircraft operating envelope is demanding of the inlet when the pressures to reduce size cost, weight, and drag are obvious; the inlet separates at the edges of the envelope; the separation can be reduced by applying well known scaling laws; this asymmetric separation can degrade the compressor surge margin; and the stability margin of the engine can be affected by other features of the inlet. ESA

N93-18723# Rolls-Royce Ltd., Derby (England). Compressor Engineering Dept.
STALL IN AXIAL FLOW AERO ENGINE COMPRESSORS
CHRISTOPHER J. FREEMAN *In* VKI, Axial Flow Compressors, Volume 1 30 p 1992
Avail: CASI HC A03/MF A04

The inception of stall in an aeroengine compressor over a range of speeds and the post stall behavior are described.

Reference is made to the varying matching and system response as the speed is increased and the effects demonstrated on a single shaft gas turbine. In particular, the following are detailed: surge and stall in axial compressors, compressor matching, low speed stalls, mid speed stalls, stalls ending in rotating stalls, high speed surges, contour plots of stage 1, 4, and 7 pressures, and compressor behavior during surge. ESA

N93-18724# Cambridge Univ. (England). Whittle Lab.
STALL AND SURGE IN AXIAL FLOW COMPRESSORS
IVOR J. DAY *In* VKI, Axial Flow Compressors, Volume 1 35 p 1992
Avail: CASI HC A03/MF A04

Detrimental effects of rotating stall and surge on compressor performance is discussed. Stall and surge in axial flow compressors is introduced from first principles and in an experimental nature. The following are described: fully developed rotating stall, fully developed surge, stall inception, surge inception, and the dividing line between stall and surge. ESA

N93-18725# Cambridge Univ. (England). Whittle Lab.
ACTIVE CONTROL OF STALL AND SURGE
IVOR J. DAY *In* VKI, Axial Flow Compressors, Volume 1 39 p 1992
Avail: CASI HC A03/MF A04

The use of active control to avoid the detrimental effects of rotating stall and surge on compressor performance is discussed. The following are detailed: the active control of surge on centrifugal compressors; the active control of stall in axial compressors, covering supressions of both long length and short length scale disturbances; and the active control of surge in an axial compressor. ESA

N93-18726# Cornell Univ., Ithaca, NY. Sibley School of Mechanical and Aeronautical Engineering.
STALL TRANSIENTS INCLUDING EFFECTS OF INLET DISTORTION AND INTAKE GEOMETRY
F. K. MOORE *In* VKI, Axial Flow Compressors, Volume 1 80 p 1992
Avail: CASI HC A05/MF A04

Combined cycle theory and its enabling approximations (differential equations for stall transients) are reviewed. Developments to the theory are described: amendment to include inlet flow distortion and estimation of steady stall margin. Advances in improving the physical models used in the theory, especially those pertaining to the inlet flow, compressibility, and the axisymmetric characteristic are discussed. Computational efforts to properly treat the shape of circumferential waves and to correctly analyze potential flow in an ideal inlet are addressed. The relation of the transient theory to modern nonlinear mechanics is noted in bifurcation analysis. ESA

N93-18727# Cranfield Inst. of Tech., Bedford (England).
EXPERIMENTAL INVESTIGATION OF ROTATING STALL IN A MISMATCHED THREE STAGE AXIAL FLOW COMPRESSOR
G. L. GIANNISSIS, A. B. MCKENZIE, and R. L. ELDER *In* VKI, Axial Flow Compressors, Volume 1 19 p 1992
Avail: CASI HC A03/MF A04

An examination of rotating stall in a low speed three stage axial flow compressor operating with various degrees of stage mismatch is reported. The objective was to simulate the mismatching which occurs in high speed multistage compressors when operating near surge. The study of the stall zones involved the use of fast response measurement techniques. The study clearly shows how stages can operate in an axisymmetric fashion even when heavily stalled, rotating stall inception requiring the stall of more than one stage. Conditions required for full span and part span stall are compared and the part span stall structure is suggested to be the more relevant to high speed multistage compressors. ESA

N93-18728# Cranfield Inst. of Tech., Bedford (England).
APPLICATION OF RECESS VANED CASING TREATMENT TO AXIAL FLOW FANS
A. R. AZIMIAN, R. L. ELDER, and A. B. MCKENZIE *In* VKI, Axial Flow Compressors, Volume 1 25 p 1992
Avail: CASI HC A03/MF A04

The effect of applying a vaned recessed casing treatment to a single stage axial flow fan was investigated. The influence of the axial position of the recess relative to the rotor leading edge and other geometrical modifications of the vane passage were examined. Significant improvements in stall margin were observed without (in some builds) loss in peak efficiency. Slow and fast frequency response yawmeter probes were used to examine both the steady flow conditions and the unsteady flow caused by rotating stall. ESA

N93-18729# Cranfield Inst. of Tech., Bedford (England).
A STUDY OF STALL IN A LOW HUB/TIP RATIO FAN
M. SOUDRANAYAGAM and R. L. ELDER *In* VKI, Axial Flow Compressors, Volume 1 30 p 1992
Avail: CASI HC A03/MF A04

An investigation to define the process of rotating stall inception in a low speed, low hub/tip ratio fan is presented. Based on elementary cascade analysis, the fan would be expected to stall from the root, however, considerable experimental evidence indicates that tip stall is more frequently incurred. A study of streamtube contraction indicates that the root rematches to a more stable operating point, thus, alleviating some of the problems in that region. The experimental investigation was undertaken on an isolated rotor with successive build modifications to increase the likelihood of rotating stall inception at the root. It was apparent that real fluid effects tended to steepen the root pressure rise characteristic, thus, enhancing the stability in that region. The performance of the fan at the tip tended to be poor providing a pressure characteristic with a lower negative gradient than anticipated indicating less stability than simple flow models would suggest. Hot wire flow mapping at the rotor exit supported the overall conclusion that the rotor showed a strong reluctance to stall at the root apparently due to 'centrifuging' of the boundary layer towards the tip. ESA

N93-18730# Rolls-Royce Ltd., Derby (England). Compressor Engineering Dept.
ENDWALL FLOWS AND BLADING DESIGN FOR AXIAL FLOW COMPRESSORS
CHRISTOPHER J. ROBINSON *In* VKI, Axial Flow Compressors, Volume 1 136 p 1992 Sponsored in part by Department of Trade and Industry
Avail: CASI HC A07/MF A04

Literature relevant to blading design in the endwall region is reviewed, and important three dimensional flow phenomena occurring in embedded stages of axial compressors are described. A low speed axial flow four stage compressor rig is described and bladings studied are detailed: two conventional and two with end bends. The application of a three dimensional Navier-Stokes solver to the bladings' stators, to assess the effectiveness of the code, is reported. Calculation results of exit whirl angles, losses, and surface static pressures are compared with experiment. ESA

N93-18731# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
AXIAL FLOW COMPRESSORS, VOLUME 2
1992 332 p Lecture series held in Rhode-Saint-Genese, Belgium, 27-31 Jan. 1992
(ISSN 0377-8312)
(VKI-LS-1992-02-VOL-2; ETN-92-92165) Avail: CASI HC A15/MF A03

Lectures on the following are presented: modeling and measurement techniques for rotating stall in unsteady loss/flowfield; the determination of the zone of the stall cell by means of baroclinic wave theory; rotating stall cell and von Karman

vortex street; and the performance of controlled diffusion blades. ESA

N93-18732# Von Karman Inst. for Fluid Dynamics, Rhode-Saint-Genese (Belgium).
ROTATING STALL: MODELING-MEASUREMENT TECHNIQUES; UNSTEADY LOSS-UNSTEADY FLOW FIELD
FRANS A. E. BREUGELMANS and P. LIPPERT *In its* Axial Flow Compressors, Volume 2 205 p 1992
Avail: CASI HC A10/MF A03

A study to find a method which predicts, based on the single stage characteristics of a multistage compressor, the position of the rotating stall line, is presented. Restricted to the big stall phenomenon, the mass flow rate of the stalled compressor and the delivered pressure rise were to be determined. A literature survey shows that rotating stall is extensively investigated. In spite of the large amount of studies, the physical reasons of the phenomenon are still unknown. A review of the different approaches is given. To determine the pressure rise and the stage loading during stall in a multistage compressor, a numerical analysis was carried out. A model based on experimental results taken in the rotating stall region in a single and multistage compressor is described. The model of the stalled flow was calibrated with inhouse data and applied to compressor builds taken from literature. A good agreement between the measured flow coefficient and pressure rise and the predicted values was obtained. ESA

N93-18733# Technische Univ., Hanover (Germany).
DETERMINATION OF THE ZONE OF THE STALL CELL BY MEANS OF THE BAROCLINIC WAVE THEORY
Y. N. CHEN, U. HAUPT, U. SEIDEL, and M. RAUTENBERG *In* VKI, Axial Flow Compressors, Volume 2 11 p 1992 Sponsored by DFG
Avail: CASI HC A03/MF A03

For axial compressor flow, the determination of the stall cell as the area enclosed by the baroclinic waves of the inlet and outlet is shown. Axial and tangential velocities are shown. The determination of the meridional recirculation and of the tangential recirculations around the stall cell bubble are shown. ESA

N93-18734# Technische Univ., Hanover (Germany). Inst. of Turbomachinery.
ROTATING STALL CELL AND VON KARMAN VORTEX STREET: A METEOROLOGICAL THEORY
Y. N. CHEN (Sulzer Bros. Ltd., Winterthur, Switzerland), U. HAUPT, U. SEIDEL, and M. RAUTENBERG *In* VKI, Axial Flow Compressors, Volume 2 73 p 1992
Avail: CASI HC A04/MF A03

A meteorological theory is established for the rotating stall in axial turbocompressors. This is guided by the Rossby wave of the blade channels under the action of the baroclinic waves in the annular spaces in front of and behind the rotor and the circular Karman vortex street around the circumference of the rotor. The following are described: derivation of the established stall cell as a bubble guided by a Karman vortex pair; the reverse flow as the initiating factor for the inception of rotating stall; baroclinic wave and thermal wind; and inception of the rotating stall by intensified reverse flow. ESA

N93-18735# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Cologne (Germany).
PERFORMANCE OF CONTROLLED DIFFUSION BLADES
HANS STARKEN *In* VKI, Axial Flow Compressors, Volume 2 47 p 1992
Avail: CASI HC A03/MF A03

The development of blade design methods for axial flow compressors is addressed. The introduction gives a review of the techniques developed over recent years. Subsonic and supercritical pressure distributions are discussed. Criteria for the supercritical compressor blade suction surface pressure distribution design are given. ESA

N93-18862*# Massachusetts Inst. of Tech., Cambridge. Gas Turbine Lab.
ACTIVE STABILIZATION TO PREVENT SURGE IN CENTRIFUGAL COMPRESSION SYSTEMS Final Technical Report, 1 Dec. 1986 - 29 Feb. 1992
ALAN H. EPSTEIN, EDWARD M. GREITZER, JON S. SIMON, and LENA VALAVANI Jan. 1993 248 p
(Contract NAG3-770)
(NASA-CR-191625; NAS 1.26:191625) Avail: CASI HC A11/MF A03

This report documents an experimental and analytical study of the active stabilization of surge in a centrifugal engine. The aims of the research were to extend the operating range of a compressor as far as possible and to establish the theoretical framework for the active stabilization of surge from both an aerodynamic stability and a control theoretic perspective. In particular, much attention was paid to understanding the physical limitations of active stabilization and how they are influenced by control system design parameters. Previously developed linear models of actively stabilized compressors were extended to include such nonlinear phenomena as bounded actuation, bandwidth limits, and robustness criteria. This model was then used to systematically quantify the influence of sensor-actuator selection on system performance. Five different actuation schemes were considered along with four different sensors. Sensor-actuator choice was shown to have a profound effect on the performance of the stabilized compressor. The optimum choice was not unique, but rather shown to be a strong function of some of the non-dimensional parameters which characterize the compression system dynamics. Specifically, the utility of the concepts were shown to depend on the system compliance to inertia ratio ('B' parameter) and the local slope of the compressor speedline. In general, the most effective arrangements are ones in which the actuator is most closely coupled to the compressor, such as a close-coupled bleed valve inlet jet, rather than elsewhere in the flow train, such as a fuel flow modulator. The analytical model was used to explore the influence of control system bandwidth on control effectiveness. The relevant reference frequency was shown to be the compression system's Helmholtz frequency rather than the surge frequency. The analysis shows that control bandwidths of three to ten times the Helmholtz frequency are required for larger increases in the compressor flow range. This has important implications for implementation in gas turbine engines since the Helmholtz frequencies can be over 100 Hz, making actuator design extremely challenging. Author

N93-19101# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
THE EFFECTS OF VISCOSITY ON A CONICALLY DERIVED WAVERIDER M.S. Thesis
JAMES A. MUNDY Dec. 1992 58 p
(AD-A259019; AFIT/GAE/ENY/92D-23) Avail: CASI HC A04/MF A01

This study investigated the effects of the interaction between the viscous boundary layer and the shock wave produced by a Mach 10 inviscid optimized waverider. An implicit, Roe flux-splitting algorithm, developed by WL/FIMM, was used to solve the flow field. A validation for the inviscid version of the CFD algorithm was accomplished by comparing the numerical data produced by the CFD code to the analytic results derived by Rasmussen, and by comparison to results of the explicit version of the same Roe flux-splitting code. The computational results compared favorably. The inviscid case studied using the implicit code produced results identical, for all practical purposes, to those of the explicit code, though approximately twice as quickly. The results of the viscous flow case matched well with the results predicted by theory. The lift to drag ratio calculated, 5.74, is comparable to the results of other researchers. GRA

N93-19331*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
COOLED SPOOL PISTON COMPRESSOR Patent Application

B. G. MORRIS, inventor (to NASA) 29 Dec. 1992 20 p
(NASA-CASE-MSC-22020-1; NAS 1.71:MSC-22020-1;
US-PATENT-APPL-SN-998062) Avail: CASI HC A03/MF A01

A hydraulically powered gas compressor receives low pressure gas and outputs a high pressure gas. The housing of the compressor defines a cylinder with a center chamber having a cross-sectional area less than the cross-sectional area of a left end chamber and a right end chamber, and a spool-type piston assembly is movable within the cylinder and includes a left end closure, a right end closure, and a center body that are in sealing engagement with the respective cylinder walls as the piston reciprocates. First and second annual compression chambers are provided between the piston enclosures and center housing portion of the compressor, thereby minimizing the spacing between the core gas and a cooled surface of the compressor. Restricted flow passageways are provided in the piston closure members and a path is provided in the central body of the piston assembly, such that hydraulic fluid flows through the piston assembly to cool the piston assembly during its operation. The compressor of the present invention may be easily adapted for a particular application, and is capable of generating high gas pressures while maintaining both the compressed gas and the compressor components within acceptable temperature limits. NASA

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GEOSCIENCES

Includes geosciences (general); earth resources; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

A93-18548

MOTION AND DECAY OF TRAILING VORTICES WITHIN THE ATMOSPHERIC SURFACE LAYER

V. K. SCHILLING (Hannover Univ., Hanover, Germany) Contributions to Atmospheric Physics/Beitraege zur Physik der Atmosphaere (ISSN 0005-8173) vol. 65, no. 2 May 1992 p. 157-169. Research supported by Flughafen Frankfurt/Main AG and Deutsche Lufthansa AG refs
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Results of investigations of aircraft induced trailing vortices within the atmospheric surface layer (ASL) are presented. Using a two-dimensional numerical model, the influence of stratification and wind shear on the motion, structure and decay of those vortices has been studied. It is depicted, for example, that the shifting of vortex wakes is weakly influenced by the thermal stratification of the atmosphere (in accordance with measurements of Franke, Kopp and Tetzlaff (1991), while the background wind and wind shear are found to be more important factors. Special attention is directed to formation and influence of secondary vortices. An attempt is made to describe, in which way they are responsible for the observed 'rebounding' of the primary vortices. It is found that the development of this phenomenon depends strongly on the background crosswind and may also occur in the absence of any wind shear within the ASL. Without doubt, these secondary vortices are responsible for a possible spiral path of the vortex trajectories. These phenomena have been taken into consideration (as an important factor), when problems of landing and take-off frequencies of different aircraft will be studied. Author

A93-19191

CONTROL MEASURES USED TO REDUCE COMMUNITY NOISE FROM CIVIL AVIATION IN DENMARK

HUGO L. NIELSEN (National Agency for Physical Planning, Copenhagen, Denmark) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 628-634. refs

Airport noise abatement in Denmark is discussed and compared with the practical control measures for noise abatement currently used in the U.S. The planning system, which comprises national, regional, and municipal planning, carries out zoning around all 127 airfields and airports in Denmark. The Environmental Protection Act establishes rules for environmental approval of airfields and airports. The 14 county councils grant environmental permits to airports, which may include stipulations requiring the use of operational and land-use control measures for noise abatement. A comparison with the control measures used in the U.S. shows that it might be advisable to increase the use of some control measures in Denmark. C.A.B.

A93-19192

FINAL RESULTS FROM A STUDY OF COMMUNITY RESPONSE TO AIRCRAFT NOISE AROUND OSLO AIRPORT FORNEBU

K. H. LIASJO, T. GJESTLAND, and I. GRANOIEN (Foundation for Scientific and Industrial Research, Trondheim, Norway) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 635-642. Research supported by Norwegian Civil Aviation Administration refs

Results of an extensive study on community reaction to aircraft noise carried out in the vicinity of Oslo Airport Fornebu in the spring and summer of 1989 are presented. A total of 16 annoyance variables were included in the questionnaire. The response is presented of different questions on annoyance, activity interference, and behavioral reactions as a function of EFN, the Norwegian aircraft noise index. There is a steady increase in reactions with increasing noise levels around Fornebu. For noise levels above 45 EFN there is roughly a linear relationship with noise level for activity interference, behavioral reactions, and all but two complaint actions. More people report speech interference than any other activity interference, and the rates of speech interference increase more rapidly with increasing noise level than do any other reactions. At 65 EFN aircraft noise is spontaneously mentioned as a local problem by half the exposed population. C.A.B.

A93-20579* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

VOLUME-IMAGING LIDAR OBSERVATIONS OF THE CONVECTIVE STRUCTURE SURROUNDING THE FLIGHT PATH OF A FLUX-MEASURING AIRCRAFT

EDWIN W. ELORANTA and DANIEL K. FORREST (Wisconsin Univ., Madison) Journal of Geophysical Research (ISSN 0148-0227) vol. 97, no. D17 Nov. 30, 1992 p. 18,383-18,393. Research supported by U.S. Navy refs
(Contract NAG5-902; DAAL03-86-K-0024)
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The University of Wisconsin volume imaging lidar has been used to portray images of the three-dimensional structure of clear air convective plumes in the atmosphere surrounding the flight path of the instrumented Twin Otter aircraft operated by the National Aeronautical Establishment of Canada. Lidar images provide a context for interpretation of the aircraft measurements. The position of data points within a convective element can be determined and the temporal development of the plume can be observed to time the observation with respect to the life cycle of the plume. Plots of the vertical flux of water vapor, superimposed on lidar images clearly demonstrate the well-known sampling difficulties encountered when attempting to measure fluxes near the top of the convective layer. When loran was used to determine average aircraft velocity, flight-leg-averaged horizontal winds measured by the aircraft and area-averaged winds measured by lidar agree to within 0.2 m/s in speed and 1 deg in direction. Author

A93-20586* National Aeronautics and Space Administration, Washington, DC.

SPATIAL AND TEMPORAL VARIATIONS OF THE FLUXES OF CARBON DIOXIDE AND SENSIBLE AND LATENT HEAT OVER THE FIFE SITE

R. L. DESJARDINS (Agriculture Canada, Centre for Land and Biological Resources Research, Ottawa), P. H. SCHUEPP (McGill Univ., Sainte-Anne-de-Bellevue, Canada), J. I. MACPHERSON (National Research Council of Canada, Flight Research Lab., Ottawa), and D. J. BUCKLEY (Agriculture Canada, Centre for Food and Animal Research, Ottawa) Journal of Geophysical Research (ISSN 0148-0227) vol. 97, no. D17 Nov. 30, 1992 p. 18,467-18,475. Research supported by NASA, Agriculture Canada, and National Research Council of Canada refs
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Airborne measurements of flux densities of carbon dioxide CO2, sensible heat, and latent heat (H2O) obtained over the First ISLSCP Field Experiment (FIFE) site during three intensive field campaigns in 1987 and one in 1989 are examined to characterize the spatial and temporal variations of CO2 and energy transfer processes. These data were collected by the National Research Council Twin Otter using low-level flight patterns, all flown at constant pressure altitude during relatively clear days. The spatial variations are larger in 1989 than in 1987 and a higher correlation is observed between the fluxes and the surface features. The temporal patterns are easier to characterize with the relatively homogeneous situation of 1987. Functional relationships obtained between fluxes of CO2 and latent heat, CO2 fluxes and greenness index, latent heat fluxes and greenness index, and between sensible heat fluxes and surface air temperature differences are presented for one day in 1987 and one in 1989 as an example of the kind of information that can be obtained from grid flights at constant pressure altitude. Author

A93-20591* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
FIFE ATMOSPHERIC BOUNDARY LAYER BUDGET METHODS
A. K. BETTS (Atmospheric Research, Middlebury, VT) Journal of Geophysical Research (ISSN 0148-0227) vol. 97, no. D17 Nov. 30, 1992 p. 18,523-18,531. refs
(Contract NAS5-30524; NSF ATM-90-01960)
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The budget methods and the mixed layer model employed to analyze the aircraft data from the First ISLSCP Field Experiment (FIFE) are described. Vector budgets for the mixed layer are discussed on conserved variable diagrams. Theoretical solutions are presented for the critical surface Bowen ratio that produces no boundary layer moistening or equivalent potential temperature rise as a function of the Bowen ratio at the inversion. R.E.P.

A93-20621 National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
ASSESSING SPATIAL AND SEASONAL VARIATIONS IN GRASSLANDS WITH SPECTRAL REFLECTANCES FROM A HELICOPTER PLATFORM
CHARLES L. WALTHALL (Maryland Univ., College Park) and ELIZABETH M. MIDDLETON (NASA, Goddard Space Flight Center, Greenbelt, MD) Journal of Geophysical Research (ISSN 0148-0227) vol. 97, no. D17 Nov. 30, 1992 p. 18,905-18,912. refs
(Contract RTOP 677-21-36; RTOP 677-21-40)
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The helicopter system data acquisition technique has shown to be a viable means of gathering surface data with spectral detail adequate for intersite, intrasite, and temporal characterizations and for assessing temporal and spatial variability throughout the FIFE 1987 IFCs. The successful employment of nadir measurements for grassland assessments is notable given the reflectance anisotropy (Middleton, 1992). Though only five sites were repetitively observed, the conclusions reached from this particular sample of sites agree well with assessments from other data sources (Sellars et al., 1990 and Kittel et al., 1990). R.E.P.

A93-20622 National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
VARIABILITY OF GEOPHYSICAL PARAMETERS FROM AIRCRAFT RADIANCE MEASUREMENTS FOR FIFE
GARY J. JEDLOVEC (NASA, Marshall Space Flight Center, Huntsville, AL) and ROBERT J. ATKINSON (General Electric Co., Huntsville, AL) Journal of Geophysical Research (ISSN 0148-0227) vol. 97, no. D17 Nov. 30, 1992 p. 18,913-18,924. Research supported by NASA refs
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Airborne multispectral images were gathered on two days during the First ISLCP Field Experiment (FIFE) to study the time and space variability of remotely sensed geophysical parameters over the study region. The data sets comprised multiple overflights covering approximately a 60-min period during late morning on 04 June 1987 and shortly after dark on the subsequent day. Image data from each overpass were calibrated and earth-located, with regard to each other, utilizing aircraft INS parameters and ground control points. R.E.P.

A93-22101
INTERNATIONAL CONFERENCE ON AVIATION WEATHER SYSTEMS, 4TH, PARIS, FRANCE, JUNE 24-28, 1991, PREPRINTS
Boston, MA American Meteorological Society 1991 512 p.
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The present volume on aviation weather systems discusses range and aerospace, aviation training, access to aviation weather information, and detection techniques. Attention is given to the modernization of national aviation weather systems, the economic impact of aviation weather information, aircraft icing and other weather hazards to aviation, and aviation weather forecasting. Topics addressed include systems to detect aviation weather hazards, radar applications to aviation including terminal Doppler weather radar, microbursts, and microburst detection with airborne Doppler lidar. Also discussed are weather support activities for the Space Shuttle, low-level wind-shear terminology, a comparison of several airborne measures of turbulence, a technique for nowcasting hourly snowfall, and ice prediction systems for runways. (For individual items see A93-22102 to A93-22202) P.D.

A93-22104
LOW-LEVEL WIND-SHEAR TERMINOLOGY
ROBERT L. JACKSON (NOAA, National Weather Service, Seattle, WA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 13-15. refs
Copyright

The high level of confusion at aviation weather seminars regarding the difference between nonconvective low-level wind shear (LLWS) and microbursts is addressed. A survey was taken among pilots to help determine their understanding of LLWS and microbursts. The majority of the pilots knew there was a difference between LLWS and microbursts, although 17 percent of the air transport pilots were wrong, and 26 percent of the commercial respondents didn't know. It is argued that much of the confusion would be eliminated if convective and nonconvective LLWS were each given separate terms. P.D.

A93-22113
DISTRIBUTION OF AVIATION WEATHER GRAPHICS VIA AIRLINE COMMUNICATIONS NETWORKS
MICHAEL R. CETINICH (Jeppesen DataPlan, Los Gatos, CA) *In International Conference on Aviation Weather Systems, 4th, Paris,* France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 51-55.
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Attention is given to techniques that allow for the rapid transmission of high-resolution color aviation weather graphics almost anywhere in the world, using standard airline communications networks. Flight crews and airline operations can now receive the latest high-quality weather maps before each flight, regardless of geographic location. This capability will help increase flight safety and overall efficiency, and will reduce operation costs. P.D.

A93-22114
THE FEDERAL AVIATION ADMINISTRATION (FAA) AND THE NATIONAL WEATHER SERVICE (NWS) MODERNIZATION PROGRAMS - CATALYSTS FOR CHANGE IN WEATHER SERVICES
ARTHUR SHANTZ (NCAR, Boulder, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 56-59. Research supported by NCAR and NSF refs
(Contract DTFA01-90-Z-02049)
Copyright
The new approach to data gathering, processing, analysis, and distributing functions in aviation weather that has been generated by the parallel development of the FAA and NWS is examined. A variety of airport and regional air traffic control modernization projects, planned or under way throughout the world, are in a position to create integrated weather detection zones and weather information modules. As zones of gridded, high-resolution weather detection are created along commercial air traffic arteries, mesoscale meteorological products are expected to revolutionize perceptions about the commercial potential for selling weather information. P.D.

A93-22116
POTENTIAL AIRCRAFT HAZARDS IN THE VICINITY OF CONVECTIVE CLOUDS - A REVIEW FROM THE PERSPECTIVE OF A SCALE-MODEL STUDY
ALFRED J. BEDARD, JR. (NOAA, Wave Propagation Lab., Boulder, CO) and WILLIAM CUNNINGHAM (Colorado Univ., Boulder) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 66-70. refs
Copyright
The possibilities of scale modeling a range of convective and environmental flow interactions are explored in order to study potential aircraft hazards in the vicinity of convective clouds. Conditions that may be important in convective and environmental flow interaction situations are summarized, and the important physical processes involved are identified. P.D.

A93-22118
DETECTION OF MICROBURST-RELATED GUST FRONTS USING DOPPLER RADAR
LAURIE G. HERMES (NOAA, National Severe Storms Lab., Norman, OK) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 76-80. refs
(Contract DTFA01-80-Y-10524)
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Horizontal wind fields derived from dual-Doppler observations collected every minute are used to examine the evolution of the near-surface horizontal convergence structure of the ring vortex portion for two microburst outflows. Some of the single-Doppler radar signatures evident in these microbursts and other observations associated with these events are presented and discussed. Further examination of an expanded data base of ring vortex and rotor cases using near-surface dual-Doppler and single-Doppler analyses is planned. The application of these observations for the development of an algorithm to detect the ring vortex phenomena is also discussed. P.D.

A93-22119
PRELIMINARY RESULTS OF THE DETECTION OF CLEAR AIR TURBULENCE BY THE WIND PROFILER DEMONSTRATION NETWORK
JOHN HINKELMAN, RICHARD JESUROGA, DANIEL LAW, and ADRIAN MARROQUIN (NOAA, Forecast Systems Lab., Boulder, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 81-84. refs
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During the winter of 1990-1991 the clear air turbulence (CAT) capability of wind profilers was assessed by collecting pilot reports over the Wind Profiler Demonstration Network. Pilot reports of turbulence were correlated with the profiler wind data and isentropic analysis based on conventional observations. The analysis techniques are described and the results of the comparisons are presented. The data sets acquired are similar in the several cases analyzed and show the ability of individual profiler stations and the profiler network to provide significant data inputs to help elucidate atmospheric structure asssociated with CAT occurrences and valuable inputs to CAT forecasting. Plans for a more detailed analysis of CAT measurements from wind profilers and other observing systems are discussed. P.D.

A93-22120
IMPROVEMENT IN GUST FRONT ALGORITHM DETECTION CAPABILITY USING REFLECTIVITY THIN LINES VERSUS AZIMUTHAL SHEARS
DIANA KLINGLE-WILSON (MIT, Lexington, MA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 85-89. Research sponsored by FAA refs
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The extent to which the performance of the gust front algorithm could be improved by incorporating additional radar signatures, specifically for reflectivity thin lines and/or azimuthal shears, is determined. Single Doppler radar data collected in Denver in 1988 and Kansas City in 1989, representing 229 missed and 530 detected events, are used in the analysis. Missed and detected events are considered separately in terms of strength of the event, type of signature exhibited, and improvement in percentage of total event length detected with the additional signature(s). For missed events the data indicate that thin line detection would improve performance in Denver more than in Kansas City, whereas azimuthal shear detection would result in an equal improvement in both cities. For detected events, data indicate that thin line detection would result in detecting a greater extent of the gust front than would azimuthal shear detection in both cities. The number of missed events could be reduced by using a better convergence shear-finding technique. P.D.

A93-22123
A 'NEW AGE' IN AVIATION WEATHER FORECASTING
ARTHUR L. HANSEN (FAA, Washington) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 100, 101.
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The plans of the Federation Aviation Administration and the National Weather Service to advance to a new era of aviation weather services are described. New sensors are to be evaluated or developed as required to observe the aviation impact variables of the atmosphere. Rapid scan and polarimetric radar technqiues are to be explored for possible incorporation in future airport surveillance radars. Airborne sensing of turbulence, wind shear, and humidity is to be explored and developed. P.D.

A93-22124
DEVELOPING THE AVIATION GRIDDED FORECAST SYSTEM
LYNN SHERRETZ (NOAA, Forecast Systems Lab., Boulder, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 102-105. Research supported by FAA and NOAA
Copyright
The Aviation Gridded Forecast System that NOAA's Forecast System Laboratory, which is developing as part of the effort by the National Weather Service and the Federal Aviation Administration to improve aviation weather services, is described. This effort involves implementing advanced weather sensors and advanced interactive processors, and developing the very-high-resolution gridded meteorological analyses and forecasts required to generate site-specific and timely products to support aviation decision-making. P.D.

A93-22125
THE AVIATION WEATHER PRODUCTS GENERATOR
JOHN MCCARTHY (NCAR, Boulder, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 106-111. Research supported by NCAR and NSF refs
(Contract DTFA01-90-Z-02049)
Copyright
The Aviation Weather Products Generator (AWPG) is a system developed by the Federal Aviation Administration that provides a 4D gridded observation and forecast data base for the aviation weather system. A schematic of the AWPG shows the end-state structure for both the regional and national levels, and a time evolution of the regional structure, from 1994 through 2003, as the regional SWPG becomes functional. The potential benefits from AWPG aviation weather products include reduced separation minima and runaway configuration time, increased preferred routing and dispatching efficiency, and enhanced forecast accuracy and information reliability. P.D.

A93-22127
INTEGRATED TERMINAL WEATHER SYSTEM (ITWS)
JAMES E. EVANS (MIT, Lexington, MA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 118-123. Research sponsored by FAA refs
Copyright
The paper reviews the key aviation weather needs in the terminal area and the deficiencies that will exist when the systems currently in production are deployed. The Integrated Terminal Weather System is designed to provide a vehicle for generating terminal weather products that will meet the future needs for an improved terminal capacity and efficiency of operation. An ambitious development program using functional operational prototypes to validate and refine the user requirements, operational concept, and interfaces to sensors and weather processing systems is described. P.D.

A93-22128
INTEGRATED RUNWAY METEOROLOGICAL OBSERVATION SYSTEM (IRMOS/SIOMA)
MICHEL LEROY (Meteo France, Trappes, France), DIDIER MURAGLIA (Degreane, Toulon, France), YVES MERCADIE, and PATRICK TCHANG (Societe Francaise d'Etudes et de Realisations d'Equipements Aeronautiques, Paris, France) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 124-126.
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The integrated aerodrome meteorological observation system (IRMOS/SIOMA) is based on: standardization of digital data transmission procedures through the use of a CIBUS protocol; central equipment for data acquisition and processing built around readily available commercial equipment, especially in the microcomputing field; and diffusion of meteorological data to different parts of the airport, and the collection, on a single console, of all the meteorological data required by the operator. The system features: extremely easy adaptation to the specific requirements of each airport; easy extension, without obsoleting the existing equipment, simply by adding further sensors or increasing the number of data diffusion terminals; and a highly modular system capable of providing the ideal solution for small local or regional airports just as easily as for major international airports. P.D.

A93-22130
THE METEOROLOGIST WEATHER PROCESSOR FOR U.S. NATIONAL WEATHER SERVICE UNITS AT FEDERAL AVIATION ADMINISTRATION SITES
DUANE COOLEY (Stanford Telecommunications, Inc., Washington) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 131-134. Research supported by FAA refs
Copyright
In an effort to provide more accurate, more timely, and more usefully displayed weather information for support of the national enroute air traffic control system of the U.S., meteorologist weather processors (MWPs) have been installed at 21 air route traffic control centers and at the Air Traffic Control System Command Center of the Federal Aviation Administration. The new MWPs provide color displays of radar imagery, weather satellite imagery, graphic analyses and forecasts, alphanumeric messages, and automated analyses of incoming gridded data from models run at the NMC. P.D.

A93-22131
FAA WEATHER PROCESSOR PROGRAMS - REAL-TIME DISSEMINATION OF WEATHER INFORMATION TO AVIATION END-USERS
ALFRED MOOSAKHANIAN and RONALD MCHENRY (Stanford Telecommunications, Inc., Washington) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 135-138. refs
Copyright
The paper examines the efforts of the Federal Aviation Administration to deploy a number of advanced weather data processing dissemination systems at ATC facilities within the next five years to provide accurate and timely weather information. Attention is given to the Weather Message Switching Center Replacement, the Real-time Weather Processor, and the Meteorologist Weather Processor. P.D.

A93-22133
THE METEOROLOGICAL DATA COLLECTION AND REPORTING SYSTEM - STATUS AND FUTURE DIRECTIONS
DAVID L. TAYLOR, RONNIE D. LONDOT, and GEORGE T. LIGLER (Aeronautical Radio, Inc., Annapolis, MD) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 144-146. refs
Copyright
The Meteorlogical Data Collection and Reporting System (MDCRS) collects, organizes, and distributes automated aircraft position and weather reports to the U.S. National Weather Service. While there are presently about 12,500 MDCRS reports daily, a significant increase in this volume is anticipated: MDCRS is designed to support up to 150,000 reports per day. Cost-effective expansion of MDCRS functionality to manage major elements of the aircraft meteorological reporting 'application' in an ATN environment is highly feasible. C.A.B.

A93-22134
AUTOMATED WEATHER DISTRIBUTION SYSTEM (AWDS) FOR SUPPORT OF GLOBAL AVIATION
W. R. BERGEN and P. L. MONAHAN (CONTEL Federal Systems, Westlake Village, CA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 147-152. refs
Copyright
The study examines the Automated Weather Distribution System (AWDS), an integrated imagery, graphics, alphanumeric, and data processing system which automates the weather forecasting, observing, and aviation support mission of the U.S. Air Force and Army. A brief history of the AWDS program is presented, and the final design is described from both hardware/software and functional perspectives. User interface design and system capabilities are discussed. Future system development, current operational status, and valuable lessons learned during development, test, and forecaster training are addressed. A graphical workstation monitor displaying four different product sets simultaneously, and a transportable AWDS configuration are shown. C.A.B.

A93-22136
A PROPOSED ICING SEVERITY INDEX BASED UPON METEOROLOGY
MARCIA K. POLITOVICH and WAYNE R. SAND (NCAR, Boulder, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 157-162. Research supported by FAA refs
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The efforts of NCAR to develop improved icing forecast methods and to devise a new icing severity index are described. This index is to be meteorogically based, consider those factors which affect aircraft performance, and be readily comprehended by the pilot. Factors involved in creating the new severity index, the preliminary index system, tests of that system, and possible areas of improvement are discussed. A ten-level index, with the meteorologically-based intensity of icing increasing with number, is proposed. The droplet size distribution is characterized by the median volume diameter (MVD). Measurements obtained from the University of Wyoming's King Air for two flights in upslope clouds near Denver, Colorado, in February 1990 are shown. Frequency distributions of supercooled liquid water content, temperature, and MVD are shown as well. C.A.B.

A93-22141
SEA FOG AND STRATUS - A MAJOR AVIATION HAZARD IN THE NORTHERN GULF OF MEXICO
G. A. JOHNSON and JEFFREY GRASCHEL (NOAA, National Weather Service Forecast Office, New Orleans, LA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 179-184. refs
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Techniques to help the forecaster identify synoptic patterns which are conducive to the development of sea fog and stratus in the northern Gulf of Mexico are developed. Graphical aids using important meteorological parameters are developed with an eye to eliminating loss of life and property due to aviation and marine accidents in the northern Gulf and the immediate coastal plains. A forecast technique recommended to the forecast staff at the New Orleans National Weather Service Forecast Service is highlighted. A table of recommended ceilings and visibilities for the different types of sea fog and stratus are presented. An example of computer output (forecast) from the nested grid model with analyzed parameters is shown. C.A.B.

A93-22145
OPERATIONAL AVIATION WEATHER SERVICE REQUIREMENTS
FREDERICK J. FOSS (Denver Air Route Traffic Control Center; NOAA, National Weather Service, Longmont, CO) and JOHN W. HINKELMAN, JR. (NCAR; NOAA, Forecast Systems Lab., Boulder, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 202-207. refs
Copyright
Weather-caused limitations on future automated ATC system operations and functions are addressed. The ATC automation planned by the Federal Aviation Administration involves complete automation of aircraft separation functions and automation support of air traffic planning functions. Air traffic specialists will be relieved of all traffic separation monitoring, problem detection, near-term problem resolution, clearance formulation, clearance delivery, and advisory responsibilities. The focus will be on traffic management activities involving traffic complexity and system capacity limitations. The bulk of activities required of air traffic specialists will be to develop strategies to deal with the capacity reduction caused by weather. Advanced Automation System current and forecast weather information matrices are presented. C.A.B.

A93-22146
WEATHER INFORMATION REQUIREMENTS FOR TERMINAL AIR TRAFFIC CONTROL AUTOMATION
MARK WEBER, MARILYN WOLFSON, DAVID CLARK, SETH TROXEL, APPA MADIWALE, and JOHN ANDREWS (MIT, Lexington, MA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 208-214. Research sponsored by FAA refs
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An initial study of the weather information requirements for Terminal Air Traffic Control Automation (TATCA) and their relationship to current and future systems for measurement, integration, forecasting, and dissemination of meteorological data in the terminal area is described. Available data on the breakdown of incremental IFR delay as a function of weather type indicates that, nationwide, roughly one-half of the delay occurs under relatively stable weather conditions involving ceiling and/or visibility reductions not associated with thunderstorms or heavy fog. In this case, TATCA's principal weather information requirement is a wind model to support time-to-fly predictions. TATCA operations in thunderstorms or heavy fog are considered. Over the short term, the TATCA system must be provided with the flexibility needed to adapt to the complex operational systems associated with thunderstorm activity. Over the long term, TATCA is envisioned as a supporting dynamic flight routing around storm cells as long as the convective activity is isolated and does not affect airport runways. C.A.B.

A93-22147
NUMERICAL FORECASTING OF LIQUID WATER CONTENT TO ASSESS AIRFRAME ICING RISK
R. W. LUNNON (Meteorological Office, Bracknell, United Kingdom) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 222-227. refs
Copyright
Attention is given to icing of any part of a helicopter caused by flight through supercooled liquid water. Aspects of the operation of helicopters in the North Sea in relation to the icing problem are examined. The significant aspects of the U.K. Meteorological Office quasi-operational mesoscale model, which is used as the basis of predictions, are summarized. C.A.B.

A93-22149
AN EVALUATION OF AIRCRAFT ICING FORECASTS FOR THE CONTINENTAL UNITED STATES
MARCIA K. POLITOVICH (NCAR, Boulder, CO) and RON OLSON (NOAA, National Weather Service, Kansas City, MO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 234-238. refs
(Contract DTFA01-90-Z-02005)
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An evaluation of forecasts issued by the National Aviation Weather Advisory Unit was recently undertaken. Pilot reports of icing were used to validate forecasts for a two-month period during winter 1990. Results of the evaluation, the pilot report data base, and initial steps toward improving forecast techniques are presented. Automation of objective guidance could provide consistency in forecasts and facilitate improvements in methodology, and allow more time for the forecaster to concentrate on mesoscale and local effects on the icing environment, such as terrain, large bodies of water, and convection. C.A.B.

A93-22150
LIQUID WATER PROFILING USING REMOTE SENSOR OBSERVATIONS
B. B. STANKOV, J. A. SCHROEDER, E. R. WESTWATER (NOAA, Wave Propagation Lab., Boulder, CO), and R. M. RASMUSSEN (NCAR, Boulder, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 239-246. refs
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Integrated-liquid measurements with a two-channel microwave radiometer are combined with observations from a ceilometer, a RASS, and a wind-profiling radar to profile the observed liquid and determine its temperature. Results obtained with two different combination methods are presented. It is shown that the boundaries of a supercooled liquid layer can be identified and continuously monitored with a two-channel microwave radiometer, a RASS, a ceilometer, and the moist adiabatic approximation of cloud-top. Commerical pilot reports of aircraft icing are used for verification. Two-channel ceilometer, radiosonde, and several types of cloud top estimates in a phsyical retrieval scheme are used to profile the liquid distribution. The liquid density profiles measured by research aircaft for verification are employed. It is shown that the remotely sensed, supercooled cloud was the site of numerous pilot reports of aircraft icing. C.A.B.

A93-22151
BUOYANCY WAVE HAZARDS TO AVIATION
R. J. DOVIAK (Oklahoma Univ.; NOAA, National Severe Storms Lab., Norman, OK) and D. R. CHRISTIE (Australian National Univ., Canberra, Australia) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 247-252. refs
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Flight recorded data from Delta flight 191, while on its final approach to the Dallas-Fort Worth Airport in Texas on August 2, 1985, provides evidence of a propagating horizontal vortex developing into a solitary wave disturbance. The paper determines whether evolving buoyancy waves, especially solitary waves far from their initiating source, can be a potential hazard to safe flight. It is argued that windshear hazards in the neighborhood of thunderstorms may be increased when a suitable waveguide layer is present at the surface, since the energy of downdraft outflows can then be concentrated into large amplitude solitary waves which, in turn, can carry dangerous shear away from the storm over large distances. C.A.B.

A93-22152
MAXIMUM HAIL CONCENTRATION THAT CAN BE MET BY AN AIRCRAFT IN STORMY PRECIPITATIONS
D. HUSSON and J. F. MEZEIX (Groupement National d'Etudes des Fleaux Atmospheriques, Aubiere, France) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 253-256. Research supported by SNECMA and Groupement National d'Etudes des Fleaux Atmosphriques refs
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The maximum hail concentration that can be met by an aircraft in stormy precipitations is determined through a comparison of the mass calculated by the reflectivity factor/hail concentration relationships and that measured on the ground for heavy hailfalls. On the basis of a sample of 253 hail cells, it was found that concentrations higher than 15 cu gm can be reached in thunderstorms. C.A.B.

A93-22154
DIAGNOSTIC STUDIES OF CLEAR AIR TURBULENCE IN ISENTROPIC COORDINATES
ADRIAN MARROQUIN (NOAA, Forecast Systems Lab., Boulder, CO) and BORISLAVA STANKOV (NOAA, Wave Propagation Lab., Boulder, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 262-267. refs
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Results of diagnostic studies of clear air turbulence (CAT) in which an isentropic objective analysis was used to investigate synoptic-scale and mesoscale sources of turbulence are presented. Correlations between turbulence intensity and a computed Richardson number are investigated in order to infer the adequacy of the radiosonde data over the continental U.S. for the computation of indices and for guidance of CAT forecasting. The results of these diagnostic studies may provide procedures to properly validate numerical models used in CAT forecasting. The results could be extrapolated 1 or 2 h beyond the radiosonde time, given that the suggested turbulence comes from meso- and large-scale processes. C.A.B.

A93-22158
A FINE STRUCTURE OF THE GUST FRONT OBSERVED WITH SONIC ANEMOMETER
HIROSHI NIRASAWA, HISAO OHNO, and OSAMU SUZUKI (Meteorological Research Inst., Tsukuba, Japan) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 278-280. refs
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Observations of the gust front of an active thunderstorm north of Tsukuba, Japan, in the afternoon of July 19, 1990 with three-axis anemometers are presented. The fine structure was found in the maximum horizontal wind speed area. Three cores were analyzed to be at 100-m (or 10-sec) intervals in the horizontal wind speed. The significant upward and downward motion appeared above a height of 150 m. P.D.

A93-22159
EXTREMELY LOW LEVEL JET IN THE EVENING IN KANTO PLAIN
HISAO OHNO and OSAMU SUZUKI (Meteorological Research Inst., Tsukuba, Japan) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 281, 282. refs
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Statistical features of the extremely low-level jet in the evening in Kanto Plain, Japan, are reported, with reference to Harada's (1984) results. A case study on Doppler radar observations for determining the behavior of the vertical wind shear is presented. It is found that almost all the jets appear only in the local evening and do not last long. The maximum wind levels are lower than 500 m. Insolation and orographical effects on the low-level jet formation are inferred. P.D.

A93-22161
VALIDATION OF AVIATION WEATHER PRODUCTS FOR THE ADVANCED TRAFFIC MANAGEMENT SYSTEM
RICHARD T. JESUROGA, JAMES RAMER, STEVE ALBERS (NOAA, Forecast Systems Lab., Boulder, CO), and RICHARD D. WRIGHT (DOT, Volpe National Transportation Systems Center, Cambridge, MA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 287-290. refs
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The Advanced Traffic Management System (ATMS) prototype is a development system used to experiment with concepts and demonstrate the utility of automation support for air traffic management. Employment of the ATMS prototype to integrate real-time flight data and weather information reduces the risks associated with introducing new technologies into operational traffic management environments. The rapid proliferation of novel meteorological observing systems and data integration techniques enable the Transportation Systems Center and the Forecast Systems Laboratory (FSL) to introduce advanced meteorological products into the ATMS environment for validation. FSL is developing enroute traffic management products for real-time testing and evaluation. Terminal Area products are being prototyped for Denver's Stapleton Airport to demonstrate possible uses of terminal area observations for traffic management. An ATMS operational meteorological validation exercise is to be applied to determine meteorological requirements for the Federal Aviation Administration's next-generation traffic management system. P.D.

A93-22162
THE ROLE OF NATIONAL METEOROLOGICAL SERVICES IN AVIATION SERVICING UNDER THE FINAL PHASE OF THE WORLD AREA FORECAST SYSTEM
NEIL GORDON (New Zealand Meteorological Service, Wellington) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 291-294. refs
Copyright
Implications of the further centralization of significant weather forecasting for international aviation on the role of national meteorological services in providing services for aviation are examined. The present status and future evolution of the World Area Forecast System (WAFS) are discussed. Reception of WAFS and World Weather Watch products is considered. P.D.

A93-22164
SHORT RANGE FORECASTS FOR AIR TRAFFIC CONTROL USING HIGH RESOLUTION AIRCRAFT DATA
R. W. LUNNON (Meteorological Office, Bracknell, United Kingdom) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 301-306. Research sponsored by Civil Aviation Authority refs
Copyright
In order to address the requirement of accurate forecasts for more efficient use of airspace, runway space, and fuel, the Winds Analyzed and Forecast for Tactical Aircraft Guidance over England (WAFTAGE) system has been developed. WAFTAGE's current system, application, and future plans are examined. High-resolution aircraft data and the means for transmitting them from the aircraft to the ground are discussed. The analysis and forecasting system are described in detail. Results of the application of the WAFTAGE system to data obtained in real time on August 30, 1990 are presented. Differences between observed and forecast wind fields are shown in tabular form. P.D.

A93-22167
TERMINAL FORECAST AMENDMENTS - A 'CLOUDY' ISSUE
W. L. RANAHAN (DND, Ottawa, Canada) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 316-318.
Copyright
A study of forecast amendments for ten military airports in Canada conducted to investigate amendment responsiveness and timeliness is presented. These data were analyzed along with forecast accuracy and climatological statistics to diagnose problem areas and develop options for proving terminal forecast systems. It was found that forecasts would be more reliable if issued more frequently, such as every 3 hr vs the current 6 hr. This would lessen substantially the requirement for amended forecasts, and enable the forecaster to analyze more carefully the development of weather conditions, rather than responding on impulse to rapidly changing weather not reflected in 'old' forecasts. P.D.

A93-22175
SAAW - ITALY'S ANSWER TO THE WINDSHEAR CHALLENGE
LODOVICO LA VALLE (Compagnia Italiana Servizi Tecnici, Rome, Italy) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 351-356. refs
Copyright
To address the problem of windshear detection, Italy installed in 1987 an experimental system at the airport of the island of Pantelleria. SAAW, an advanced prototype of LLWAS, was developed. Adjacent stations are positioned close to each other. UVW anemometers are used to obtain complete information on turbulence, in addition to the horizontal and vertical mean wind. A sophisticated method of analyzing short-period turbulence makes it possible to filter out accidental errors and stations which are temporarily out of order. Usual methods of meteorological analysis are applied to pass from observed wind to wind values at the grid points of a regular mesh. These second-level data are the basis for any subsequent processing. Several cases are shown in order to prove SAAW's capability for detecting local motions ranging between 400 m and 4 km. P.D.

A93-22179
THE REDESIGNED LOW LEVEL WIND SHEAR ALERT SYSTEM
F. W. WILSON, JR. (MIT, Lexington, MA) and RICHARD H. GRAMZOW (Martin Marietta Corp., Washington) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 370-375. Research sponsored by FAA refs
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Improvements in the Low Level Wind Shear Alert System (LLWAS) are described, and the performance of the updated system is evaluated. The improved algorithm is designed for use at airports of all sizes. With this improved algorithm, the system efficiently detects microbursts over the coverage area and issues a minimal number of false microburst alerts. The algorithm is very stable in the presence of subscale and short-lived meteorological events and issues acceptably few 'nuisance' alerts. P.D.

A93-22180
SEASONAL WEATHER HAZARDS
WILLY S. GOMA (Department of Meteorology, Central Forecast Office, Lusaka, Zambia) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 376, 377. refs
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Meteorological phenomena that affect aviation in southern Africa, such as heavy rains, storms, severe dust-bearing winds, and tropical cyclones, are examined. The effects of the weather on take-off delays, returned or diverted flights, and communication disruptions between ground station and aircraft are considered. P.D.

A93-22184
STATUS OF THE TERMINAL DOPPLER WEATHER RADAR ONE YEAR BEFORE DEPLOYMENT
JAMES E. EVANS (MIT, Lexington, MA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J1-J6. Research sponsored by FAA refs
Copyright
The current status and deployment strategy for the operational systems of the Terminal Doppler Weather Radar are described, and recent results from extensive testing of the radar system concept and weather information dissemination approach are presented. Tables show microburst detection performance, gust front detection performance as a function of gust front strength, and gust front/wind shift planning product performance. P.D.

A93-22187
RELIABILITY CONSIDERATIONS FOR WEATHER HAZARD WARNING RADAR
J. M. GLASS, J. G. WIELER, and R. H. HYNES (Raytheon Co., Equipment Div., Sudbury, MA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J17-J20. refs
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Some of the architectural issues of hazard warning radar systems considered in evaluating candidate design approaches are discussed, with emphasis on the relibility issues. Straightforward, dual-channel architectures offer a significant reliability gain relative to nonredundant designs, with a marked reduction in cost and complexity relative to more elaborate redundant structures. They provide a direct means of implementing equipment switchover in the event of failure, and allow repair of the redundant units while system operation continues with the available equipment. P.D.

A93-22188
TERMINAL DOPPLER WEATHER RADAR PROGRAM AT DENVER'S STAPLETON INTERNATIONAL AIRPORT DURING 1989 AND 1990
JAMES A. MOORE, LARRY CORNMAN, and CLEON BITER (NCAR, Boulder, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J21-J26. refs
(Contract DTFA01-90-Z-00049)
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The NCAR Research Applications Program conducted Terminal Doppler Weather Radar (TDWR) demonstration programs in 1989 and 1990 in order to provide wind shear warnings to air traffic personnel at Stapleton Airport in Denver, Colorado, and to evaluate the accuracy, timeliness, and utility of the wind shear products. The programs feature: the integration of the TDWR alert products with information provided from the Stapleton Airport network expansion Low Level Wind Shear Alert System (LLWAS); preparation and dissemination of nowcasting products to Federal Aviation Administration (FAA) personnel to assist in operational planning; advanced display presentation of wind shear alert products, gust front, storm motion, precipitation intensity, and nowcast information at the FAA Denver Tower, Terminal Radar Control Facility, and Air Route Traffic Control Center; and the formation, extensive interaction, and counsel from the TDWR/LLWAS User Working Group to guide product development and implementation of the TDWR system and to meet user needs. P.D.

A93-22190
PERFORMANCE RESULTS AND POTENTIAL OPERATIONAL USES FOR THE PROTOTYPE TDWR MICROBURST PREDICTION PRODUCT
STEVEN D. CAMPBELL (MIT, Lexington, MA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J33-J36. Research sponsored by FAA refs
(Contract F19628-90-C-0002)
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The study presents a proposed new Terminal Doppler Weather Radar (TDWR) product for microburst prediction (MBP), which provides the ability to predict microbursts prior to the onset of surface outflow. The MBP product uses the ability of the TDWR to scan aloft for precursor signatures which indicate that a microburst is about to occur. The potential usefulness of the MBP product is illustrated with an example that occurred during operational testing during the summer of 1990. P.D.

A93-22191
AN IMPROVED GUST FRONT DETECTION ALGORITHM FOR THE TDWR
MICHAEL D. EILTS (NOAA, National Severe Storms Lab., Norman, OK), STEPHEN H. OLSON (MIT, Lexington, MA), GREGORY J. STUMPF (NOAA, National Severe Storms Lab.; Cooperative Inst. for Mesoscale Meteorological Studies, Norman, OK), LAURIE G. HERMES (NOAA, National Severe Storms Lab., Norman, OK), ADAM ABREVAYA, JAMES CULBERT (MIT, Lexington, MA), KEVIN W. THOMAS, KURT HONDL (NOAA, National Severe Storms Lab.; Cooperative Inst. for Mesoscale Meteorological Studies, Norman, OK), and DIANA KLINGLE-WILSON (MIT, Lexington, MA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J37-J42. Research sponsored by FAA refs
Copyright
The study describes a new algorithm which provides improved gust front detection for the TDWR using additional radar signatures of gust fronts. The novel algorithm enhances detection and prediction of gust fronts by merging radial convergence features with azimuthal shear features, thin line features, and the predicted locations of gust fronts which are passing over the radar. The rule base used to combine detections from the four components of the algorithm into single gust front detections is described. The final product of the gust front algorithm is a smooth curve representing the location of the gust front, 10- and 20-min forecasts of gust front location, an estimate of the speed and direction of the wind behind the gust front, and an estimate of the wind shear hazard. P.D.

A93-22195
THE DETECTION AND WARNING OF LOW-LEVEL WIND SHEAR BASED ON TERMINAL SINGLE DOPPLER RADAR
H. Y. TSENG and Y. P. WEIH (Taipei Meteorological Center, Taiwan) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J55-J58. refs
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The study analyzes and states the weather pattern, Doppler radar observation, warning issuance, and the operational condition of the ATC personnel aircraft when significant low-level wind shear arose over C.K.S. Airport on April 22, 1980. The significant low-level wind shear and turbulence were caused by a cold front and the accompanying mesoscale convective thunderstorm system. Significant surface wind velocity change was also found to be one of the major causes of the low-level strong turbulence. P.D.

A93-22196
THE DYNAMICS OF MICROBURSTS AS REVEALED BY DOPPLER RADAR OBSERVATIONS AND NUMERICAL SIMULATIONS
DAVID B. PARSONS (NCAR, Boulder, CO) and ROBERT A. KROPFLI (NOAA, Wave Propagation Lab., Boulder, CO) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J59-J62. Research sponsored by NSF refs
Copyright
A 3D cloud model is used to simulate a microburst observed on May 31, 1984 during the Phoenix II convective boundary layer experiment in the vicinity of Boulder, Colorado. The simulation produced a flow similar to the observed characteristics, including those found from thermodynamic retrieval. A cold subsiding thermal is proposed as a conceptual model for this type of cooling driving microburst. As expected from this conceptual model, the presence of vertical shear decreased the downdraft intensity. It is concluded that low-shear environments produce short-lived cells but they contain relatively large maximum vertical motions and precipitation contents. P.D.

A93-22198
MICROBURST OBSERVATIONS IN TROPICAL AUSTRALIA
RODNEY J. POTTS (Bureau of Meteorology, Melbourne, Australia) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J67-J72. refs
Copyright
Doppler radar data for a 15-d period in February 1989 are examined, and the incidence and characteristics of microbursts over tropical Australia are determined. All the microbursts were associated with thunderstorms and all occurred during the afternoon or evening, consistent with the diurnal variation in the thunderstorm frequency. The data provide some indication of the frequency and intensity of events during a period of active tropical convection, as well as background for the development of operational techniques for wind shear detection at major airports in Australia. P.D.

A93-22199
DOPPLER RADAR OBSERVATION OF TORNADO AND MICROBURST AROUND CHITOSE AIRPORT
RYUICHI SHIROOKA and HIROSHI UYEDA (Hokkaido Univ., Japan) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J73-J76. refs
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A single Doppler radar is used to observe the whole life cycle of a severe thunderstorm, accompanied by a tornado, microburst, and gust front, that occurred very close to Chitose Airport, Hokkaido, Japan. Accurate positions of the tornado and its lifetime are determined from photographs of the funnel cloud. The possible mechanism of microburst generation is presented from RHI cross sections. The records of the gust front indicate the existence of strong wind shear at the airport. P.D.

A93-22200
STRUCTURE OF DOWNBURSTS ASSOCIATED WITH HEAVY RAINFALL OBSERVED IN TOKYO
AKIRA TABATA, KENJI AKEADA, MASAHITO ISHIHARA, and HITOSHI SAKAKIBARA (Meteorological Research Inst., Tsukuba, Japan) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J77-J80. refs
Copyright

The evolution of a convective cloud which produced downbursts associated with heavy rainfall observed in Tokyo on July 31, 1987 is documented. The characteristics of the downbursts are clarified via comparison with wet microbursts observed in the U.S. The convective cloud which formed in the humid environment produced heavy rain. The relative flow to the cloud transported the raindrops to the rear of the cloud, where raindrop evaporation occurred due to the entrainment of midtropospheric dry air. This mechanism produced downbursts which had a longer lifetime than wet microbursts that occur in the U.S. P.D.

A93-22201
MICROBURSTS DETECTION WITH AIRBORNE DOPPLER LIDAR
A. DOLFI, Y. AURENCHE, and D. DEROBERT (ONERA, Meudon, France) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J81-J84. Research supported by Direction Generale de l'Aviation Civile refs
Copyright

The detection capacity of an airborne Doppler lidar is studied in order to facilitate early warning of microbursts. The performances of a 10.6-micron and a 2.1-micron pulsed coherent Doppler lidar system are compared. Modelization of coherent Doppler lidar performances demonstrated the possibility of detecting microbursts with a lidar system in dry weather and medium turbulence conditions. P.D.

A93-22202
EVALUATION OF CLEAR-AIR RADAR PROUST AND DOPPLER RADAR RONSARD FOR AIRPORT LOW LEVEL-WIND SHEAR DETECTION
H. MOUNIR, F. BERTIN (Centre de Recherches en Physique de l'Environnement Terrestre et Planetaire, Saint-Maur-des-Fosses, France), C. LEROUX (Direction Generale de l'Aviation Civile, Paris, France), and G. SCIALOM (Centre de Recherches en Physique de l'Environnement Terrestre et Planetaire, Issy-les-Moulineaux, France) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. J89-J92. Research supported by CNET and Direction Generale de L'Aviation Civile refs
Copyright

The performances of the PROUST and RONSARD radars are compared for measurement of wind shear in different meteorological situations (clear air, convection cells, clouds, rain, etc.). It is shown that the RONSARD radar has considerably improved its detectability, as it is now able to observe echoes with radar equivalent reflectivity as weak as -20 dBz. In spite of the very different wavelengths used by both radars, they are able to observe the same atmospheric phenomena. P.D.

A93-22342*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
STRATOSPHERIC TURBULENCE MEASUREMENTS AND MODELS FOR AEROSPACE PLANE DESIGN
L. J. EHERNBERGER (NASA, Flight Research Center, Edwards, CA) Dec. 1992 26 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 Previously announced in STAR as N93-13288 refs
(AIAA PAPER 92-5072) Copyright

Progress in computational atmospheric dynamics is exhibiting the ability of numerical simulation to describe instability processes associated with turbulence observed at altitudes between 15 and 25 km in the lower stratosphere. As these numerical simulation tools mature, they can be used to extend estimates of atmospheric perturbations from the present gust database for airplane design at altitudes below 15 km to altitudes between 25 and 50 km where aerospace plane operation would be at hypersonic speeds. The amount of available gust data and number of temperature perturbation observations are limited at altitudes between 15 and 25 km. On the other hand, in-situ gust data at higher altitudes are virtually nonexistent. The uncertain potential for future airbreathing hypersonic flight research vehicles to encounter strong turbulence at higher altitudes could penalize the design of these vehicles by undue cost or limitations on performance. Because the atmospheric structure changes markedly with altitude, direct extrapolation of gust magnitudes and encounter probabilities to the higher flight altitudes is not advisable. This paper presents a brief review of turbulence characteristics observed in the lower stratosphere and highlights the progress of computational atmospheric dynamics that may be used to estimate the severity of atmospheric transients at higher altitudes. Author

A93-22992
CANONICAL CORRELATION RELATIONSHIPS AMONG SPECTRAL AND PHYTOMETRIC VARIABLES FOR TWENTY WINTER WHEAT FIELDS
R. M. KOROBOV and V. IA. RAILIAN (Academy of Sciences of Moldova, Inst. of Genetics, Kishinev) Remote Sensing of Environment (ISSN 0034-4257) vol. 43, no. 1 Jan. 1993 p. 1-10. refs
Copyright

Aircraft spectrometry of 20 winter wheat fields was related to plant measurements using canonical correlation in order to assess the adequacy of conventional agricultural surveys. Results confirmed the strong correlation between spectral and phytometric variables of green winter wheat canopies, but correlation decreased with crop maturation. The near infrared and red reflectances contributed most to canonical variables and had the highest correlation with phytometric features. Percent plant cover and dry above-ground phytomass related more closely to spectral reflectance than plant height and density. Results confirm the high information potential of aircraft spectrometry for estimating winter-wheat crop conditions. A.O.

N93-15839# Sandia National Labs., Albuquerque, NM.
WIND LOAD DESIGN METHODS FOR GROUND-BASED HELIOSTATS AND PARABOLIC DISH COLLECTORS
J. A. PETERKA and R. G. DERICKSON Sep. 1992 80 p
(Contract DE-AC04-76DP-00789)
(DE93-002737; SAND-92-7009) Avail: CASI HC A05/MF A01

The purpose of this design method is to define wind loads on flat heliostat and parabolic dish collectors in a simplified form. Wind loads are defined for both mean and peak loads accounting for the protective influence of upwind collectors, wind protective fences, or other wind-blockage elements. The method used to define wind loads was to generalize wind load data obtained during tests on model collectors, heliostats or parabolic dishes, placed in a modeled atmospheric wind in a boundary-layer wind-tunnel at Colorado State University. For both heliostats and parabolic dishes, loads are reported for solitary collectors and for collectors as elements of a field. All collectors were solid with negligible porosity; thus the effects of porosity in the collectors is not addressed. DOE

N93-16477# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Oberpfaffenhofen (Germany). Abteilung Meteorologische Fernerkundung.

IDENTIFICATION OF ICING WATER CLOUDS BY NOAA AVHRR SATELLITE DATA [IDENTIFIKATION VON VEREISENDEN WASSERWOLKEN MITTELS NOAA-AVHRR-SATELLITENDATEN]

KLAUS-PETER SCHICKEL, HANS-EBERHARD HOFFMANN, and KARL-THEODOR KRIEBEL Apr. 1992 47 p In GERMAN (ISSN 0939-2963)
(DLR-FB-92-11; ETN-93-92403) Avail: CASI HC A03/MF A01; DLR, Wissenschaftliches Berichtswesen, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Germany, HC

It is shown that water clouds and their top temperature can be identified from NOAA Advanced Very High Resolution Radiometer (AVHRR) data. It may lead to an overestimation of the risk of icing, because water clouds with little Liquid Water Content (LWC) are not distinguished from those with a sufficiently high LWC. Icing can be partly underestimated on account of undetected water clouds underneath ice clouds. The technique to determine water cloud from AVHRR data is presented. The results are validated in 21 cases by airborne measurements. The possibility of improving the icing forecast by using the LWC and its derivation for AVHRR data is discussed. ESA

N93-18587# Argonne National Lab., IL.

AQUIS: A PC-BASED AIR QUALITY AND PERMIT INFORMATION SYSTEM

A. E. SMITH, C. C. HUBER, J. TSCHANZ, and J. S. RYCKMAN, JR. 1992 13 p Presented at the International Symposium on Energy, Environment and Information Management, Argonne, IL, 15-18 Sep. 1992
(Contract W-31-109-ENG-38)
(DE92-040092; ANL/CP-76983; CONF-9209160-20) Avail: CASI HC A03/MF A01

The Air Quality Utility Information System (AQUIS) was developed to calculate and track emissions, permits, and related information. The system runs on IBM-compatible personal computers using dBASE 4. AQUIS tracks more than 900 data items distributed among various source categories and allows the user to enter specific information on permit control devices, stacks, and related regulatory requirements. The system is currently operating at seven US Air Force Materiel Command facilities, large industrial operations involved in the repair, and maintenance of aircraft. Environmental management personnel are responsible for the compliance status of as many as 1,000 sources at each facility. The usefulness of the system has been enhanced by providing a flexible reporting capability that permits users who are unfamiliar with database structure to design and prepare reports containing specified information. In addition to the standard six pollutants, AQUIS calculates compound-specific emissions and allows users to enter their own emission estimates. This capability will be useful in developing air toxics inventories and control plans. DOE

N93-18705# Midwest Research Inst., Golden, CO. National Renewable Energy Lab.

A DISCUSSION OF THE RESULTS OF THE RAINFLOW COUNTING OF A WIDE RANGE OF DYNAMICS ASSOCIATED WITH THE SIMULTANEOUS OPERATION OF ADJACENT WIND TURBINES

N. KELLEY, G. DESROCHERS, J. TANGLER, and B. SMITH Oct. 1992 9 p Presented at the Windpower 1992, Seattle, WA, 19-23 Oct. 1992
(Contract DE-AC02-83CH-10093)
(DE93-000016; NREL/TP-442-5159; CONF-921049-2) Avail: CASI HC A02/MF A01

The objective of this study was to provide a fatigue load comparison between two identical wind turbines employing different rotor designs. One turbine was fitted with a rotor consisting of a set of NREL (SERI) thin-airfoil blades while the other rotor included the original-equipment AeroStar blades. The data discussed are based on sample load populations derived from the rainflow cycle counting of 405, 10-minute records specifically collected over a wide range of inflow turbulence conditions. The results have shown that the statistical structure of the alternating load cycles on both turbines can be described as a mixture of three stochastic processes. We noted a high degree of load distribution similarity between the two turbines, with the differences attributable to either rotor weight or swept area. DOE

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MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

A93-18316

A NEW METHOD FOR DETERMINING THE NUMBER OF FLIGHT VEHICLE PROTOTYPES SUBJECT TO FULL-SCALE TESTING [NOVYI METOD OPREDELENIIA KOLICHESTVA OPYTNYKH OBRAZTSOV LETATEL'NYKH APPARATOV NA NATURNYE ISPYTANIIA]

B. E. ASEEV *In* Rocket and space technology - The ideas of K.E. Tsiolkovsky and modern development; Lectures Devoted to K.E. Tsiolkovsky's Ideas, 25th, Kaluga, Russia, Sept. 11-14, 1990, Transactions Moscow AN SSSR, Institut Istorii Estestvoznaniia i Tekhniki 1991 p. 73-77. In Russian. refs
Copyright

An attempt is made to develop a systems approach to the full-scale testing of flight vehicles. A formula is obtained for determining the number of vehicle prototypes required for obtaining reliable results in full-scale testing. The advantages of the approach proposed here over the existing methods are discussed. V.L.

A93-18373

DEVELOPMENT OF A PROTOTYPE OF AN EXPERT SYSTEM FOR THE DESIGN OF COMPREHENSIVE SCIENTIFIC-TECHNICAL DEVELOPMENT PROGRAMS FOR CIVIL AVIATION [RAZRABOTKA DEMONSTRATSIONNOGO OBRAZTSA EKSPERTNOI SISTEMY DLIA RAZRABOTKI KOMPLEKSNYKH NAUCHNO-TEKHNICHESKIKH PROGRAMM RAZVITIIA GRAZHDANSKOI AVIATSII]

K. P. DYNNIK and V. P. ZHDANOV *In* Improvement of aircraft maintenance methods Riga Rizhskii Institut Inzhenerov Grazhdanskoi Aviatsii 1991 p. 102-106. In Russian.
Copyright

A prototype of an expert system to be used as a tool in the design of civil aviation development programs is described. The expert system contains related knowledge bases in such areas as ecology of civil aviation, profitability of the industry, stability of civil aviation against external factors, flight safety, quality of passenger service, and labor economy. The utility of the expert system is illustrated by an example. V.L.

A93-18762

EXPERT SYSTEMS FOR MAINTENANCE ENGINEERING

MITCH M. GRIGORIU (Advanced Expert Systems, Ltd., Derby, United Kingdom) *In* Artificial intelligence techniques for improving aircraft maintenance efficiency; Proceedings of the Conference, London, United Kingdom, Feb. 21, 1991 London Royal Aeronautical Society 1991 p. 1.1-1.9. refs
Copyright

In this paper expert systems technology is explained, and how it can be applied to 'real' aircraft maintenance problems is shown. Also described is how expert systems can enhance human expertise and allow it to be used more efficiently in the specific working environment of aircraft maintenance. The reasons for using expert systems technology in aircraft maintenance are explained. Author

A93-18764

THE ROYAL AIR FORCE EXPERIENCE OF ARTIFICIAL INTELLIGENCE AIRCRAFT MAINTENANCE

G. SADLER (RAF, London, United Kingdom) *In* Artificial intelligence techniques for improving aircraft maintenance efficiency; Proceedings of the Conference, London, United Kingdom, Feb. 21, 1991 London Royal Aeronautical Society 1991 p. 3.1-3.19.

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A development history and current status evaluation are presented for the RAF's use of AI techniques in aircraft maintenance, primarily in the form of expert systems. It has been established that software configuration control within a centralized organization is essential to prevent the emergence in the field of competing and even mutually contradictory expert-system units. It is noted that future development of aircraft maintenance-related AI must maximize the embedding of such techniques within comprehensive, mutually-dependent systems. O.C.

A93-19080

A FAST ALGORITHM FOR OBTAINING DENSE DEPTH MAPS FOR HIGH SPEED NAVIGATION

PAYMAN KHALILI and RAMESH JAIN (Michigan Univ., Ann Arbor) *In* Mobile robots V; Proceedings of the Meeting, Boston, MA, Nov. 8, 9, 1990 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 210-221. refs

Copyright

An approach based on an intensity image segmentation algorithm followed by local surface fitting is described. A reliable environment model is presented that combines depth maps obtained over time from different viewpoints. It takes a total of 40 seconds to create a dense depth map and update the environment model on the basis of a Silicon Graphics Iris GTX computer with a single processor. O.G.

A93-19101

A FORMALIZATION AND IMPLEMENTATION OF TOPOLOGICAL VISUAL NAVIGATION IN TWO DIMENSIONS

JOHN R. KENDER, IL-PYUNG PARK, and DAVID YANG (Columbia Univ., New York) *In* Mobile robots V; Proceedings of the Meeting, Boston, MA, Nov. 8, 9, 1990 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1991 p. 476-489. Research supported by DARPA refs

(Contract DACA76-86-C-0024)

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A model of topological visual navigation in 2D spaces is formalized and implemented. Emphasis is placed on the methods of qualitative visual descriptions of objects and environments, and the methods and efficiency of direction giving through visual landmarks. The domain under consideration is a formalized variant of the visual world seen by a level-flying helicopter whose perception is limited to a narrow field of view, and whose visual axis is normal to the world below it. Particular attention is given to the abstract problem of how to optimally choose visual landmarks and their sensory features in order to describe and descriminate objects, and how to create short or efficient sequences of such descriptions for low cost qualitative navigation. O.G.

A93-19557

EXPERT SYSTEMS FOR THE SIMULATION OF GAS TURBINE ENGINES

G. TORELLA (Italian Air Force Academy, Pozzuoli, Italy) Jun. 1992 12 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs

(ASME PAPER 92-GT-408)

The possibility to develop effective expert systems for the simulation, the monitoring, and the diagnostics of gas turbine engines is explored. The development of suitable knowledge bases and expert systems for different activities is considered. These systems give operating limits of the engine and the required control laws for reaching assigned values of performance. Other expert systems developed for fault simulation are examined. The methods and several applications of the developed codes are presented. C.A.B.

A93-19576

ACCURACY AND EFFICIENCY ASSESSMENTS FOR A WEAK STATEMENT CFD ALGORITHM FOR HIGH-SPEED AERODYNAMICS

G. S. IANNELLI and A. J. BAKER (Tennessee Univ., Knoxville) Jun. 1992 7 p. ASME, International Gas Turbine and Aeroengine Congress and Exposition, 37th, Cologne, Germany, June 1-4, 1992 refs

(ASME PAPER 92-GT-433)

A bilinear finite element, implicit Runge-Kutta space-time discretization has been established for an aerodynamics weak statement CFD algorithm. The algorithm admits real-gas effects simulation, for reliable hypersonic flow characterization, via an equilibrium reacting air model. The terminal algebraic system is solved using an efficient block-tridiagonal quasi-Newton linear algebra procedure that employs tensor matrix product factorizations within a lexicographic mesh-sweeping protocol. A block solution-adaptive remeshing, for totally arbitrary convex elements, is also utilized to facilitate accurate shock and/or boundary layer flow resolution. Numerical validations are presented for representative benchmark supersonic-hypersonic aerodynamics problem statements. Author

A93-20172#

A PERFORMANCE COMPARISON OF MASSIVELY PARALLEL PARABOLIZED NAVIER-STOKES SOLUTIONS

A. K. STAGG (Texas Univ., Austin), D. D. CLINE, J. N. SHADID (Sandia National Labs., Albuquerque, NM), and G. F. CAREY (Texas Univ., Austin) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(AIAA PAPER 93-0059)

A massively parallel formulation for the solution of the Parabolized Navier-Stokes equations has been developed for Multiple Instruction, Multiple Data (MIMD) computers. All functionality of the serial version of the code has been preserved in the parallel implementation, including grid generation, linear system solvers, and shock fitting. The computational domain is automatically decomposed and load balanced on individual processing elements. Performance timings are carried out for various MIMD architectures demonstrating speedups of over 10 times conventional vector supercomputers. Numerical tests indicate high parallel efficiency, with fixed solution time as the computational work is scaled with the number of processors. Author

A93-20301* National Aeronautics and Space Administration, Washington, DC.

AIAA/USAF/NASA/OAI SYMPOSIUM ON MULTIDISCIPLINARY ANALYSIS AND OPTIMIZATION, 4TH, CLEVELAND, OH, SEPT. 21-23, 1992, TECHNICAL PAPERS. PTS. 1 & 2

Washington American Institute of Aeronautics and Astronautics 1992 p. Pt. 1, 596 p.; pt. 2, 621 p.

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The papers presented at the symposium cover aerodynamics, design applications, propulsion systems, high-speed flight, structures, controls, sensitivity analysis, optimization algorithms, and space structures applications. Other topics include helicopter rotor design, artificial intelligence/neural nets, and computational aspects of optimization. Papers are included on flutter calculations for a system with interacting nonlinearities, optimization in solid rocket booster application, improving the efficiency of aerodynamic shape optimization procedures, nonlinear control theory, and probabilistic structural analysis of space truss structures for nonuniform thermal environmental effects. (For individual items see A93-20302 to A93-20417) V.L.

A93-20318*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

MULTIDISCIPLINARY PROPULSION SIMULATION USING NPSS

RUSSELL W. CLAUS, AUSTIN L. EVANS, and GREGORY J. FOLLEN (NASA, Lewis Research Center, Cleveland, OH) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 191-196. refs
(AIAA PAPER 92-4709) Copyright

The current status of the Numerical Propulsion System Simulation (NPSS) program, a cooperative effort of NASA, industry, and universities to reduce the cost and time of advanced technology propulsion system development, is reviewed. The technologies required for this program include (1) interdisciplinary analysis to couple the relevant disciplines, such as aerodynamics, structures, heat transfer, combustion, acoustics, controls, and materials; (2) integrated systems analysis; (3) a high-performance computing platform, including massively parallel processing; and (4) a simulation environment providing a user-friendly interface. Several research efforts to develop these technologies are discussed. V.L.

A93-20343
EXACT SOLUTION SENSITIVITIES FOR BOUNDARY ELEMENT AERODYNAMICS CODES
MICHAEL A. EPTON (Boeing Co., Seattle, WA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 442-464. refs
(AIAA PAPER 92-4745) Copyright

An integral equation for the parametric sensitivity of the solution to the Prandtl-Glauert equation is derived. With appropriate attention to the computation of force and moment vectors, this leads to computation of objective function sensitivities that are exact for the discretized problem. The integral equation for the solution sensitivity is interpreted in terms of transpiration boundary conditions, resulting in a critique of conventional transpiration modeling. By means of specific examples from linear potential flow, it is shown that conventional transpiration fails to be mass-conservative, while at the same time enforcing a spurious irrotationality condition. Author

A93-20350
ON ALTERNATIVE PROBLEM FORMULATIONS FOR MULTIDISCIPLINARY DESIGN OPTIMIZATION
EVIN J. CRAMER, PAUL D. FRANK, GREGORY R. SHUBIN (Boeing Co., Seattle, WA), and J. E. DENNIS, JR. (Rice Univ., Houston, TX) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 518-530. refs
(AIAA PAPER 92-4752) Copyright

Alternative ways of formulating multidisciplinary design optimization (MDO) problems are examined. In particular, consideration is given to three fundamental approaches to MDO formulation: the multidisciplinary feasible approach, the individual discipline feasible approach, and the all-at-once approach. The features of the three approaches are compared, and the potential performance of each approach is assessed. V.L.

A93-20351*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
OBSERVATIONS ON COMPUTATIONAL METHODOLOGIES FOR USE IN LARGE-SCALE, GRADIENT-BASED, MULTIDISCIPLINARY DESIGN
P. A. NEWMAN (NASA, Langley Research Center, Hampton, VA), G. J.-W. HOU (Old Dominion Univ., Norfolk, VA), J. E. JONES (U.S. Army, Aviation Systems Command, Hampton, VA), A. C. TAYLOR, III, and V. M. KORIVI (Old Dominion Univ., Norfolk, VA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 531-542. refs
(AIAA PAPER 92-4753) Copyright

Various computational methodologies relevant to large-scale multidisciplinary gradient-based optimization for engineering systems design problems are examined with emphasis on the situation where one or more discipline responses required by the optimized design procedure involve the solution of a system of nonlinear partial differential equations. Such situations occur when advanced CFD codes are applied in a multidisciplinary procedure for optimizing an aerospace vehicle design. A technique for satisfying the multidisciplinary design requirements for gradient information is presented. The technique is shown to permit some leeway in the CFD algorithms which can be used, an expansion to 3D problems, and straightforward use of other computational methodologies. V.L.

A93-20366*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
GEOMETRIC REQUIREMENTS FOR MULTIDISCIPLINARY ANALYSIS OF AEROSPACE-VEHICLE DESIGN
ROBERT E. SMITH and PATIRCA A. KERR (NASA, Langley Research Center, Hampton, VA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 686-694. refs
(AIAA PAPER 92-4773) Copyright

The geometric requirements for creating surfaces and grids for multidisciplinary analysis and optimization of aerospace-vehicle designs are described. Geometric surface representations are outlined and compared. Directions for future designs are proposed. High-speed civil transport aircraft configurations are targeted to demonstrate the processes. Author

A93-20394#
EXAMPLES OF DYNAMIC RESPONSE OPTIMIZATION USING MSC/NASTRAN
E. H. JOHNSON, G. J. MOORE, and K. IZADPANAH (MacNeal-Schwendler Corp., Los Angeles, CA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 959-967. Research supported by Nissan Motor Co refs
(AIAA PAPER 92-4814) Copyright

The application of MSC/NASTRAN, a large scale commercial code, to the optimal design of structures undergoing dynamic excitation is demonstrated using four simple examples. Both frequency and time dependent responses are demonstrated. The disjoint nature of the design space for the example cases is discussed. That is, a given design task can exhibit local minima that are separated from one another by portions of the design space where the designs are infeasible. Concluding remarks discuss how the methodology demonstrated in the simple examples of this paper can be extended using the generality and flexibility of a large structural analysis system. In addition, some comments are made on further work that could be done to extend the application and functionality of dynamic response optimization. Author

A93-20411#
DESIGN VECTOR PARALLELIZATION TO SPEEDUP THE STRUCTURAL OPTIMIZATION PROCESS
ERIC W. MALMBORG (Pratt & Whitney Group, East Hartford, CT) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1992 p. 1111-1114. refs
(AIAA PAPER 92-4834) Copyright

A structural optimization program architecture is presented that reduces elapsed analysis time by employing parallel processing during gradient calculations. Gradient analysis elapsed time is shown to decrease as the number of processors used is increased.

These lower gradient times produce an overall reduction in the optimization analysis time. General purpose finite element and numerical optimization programs, MSC/NASTRAN and DOT, are coupled to model generating and results processing routines via a UNIX C-Shell. The resulting program framework has general applicability due to the modular coding. A multi-processor shared memory workstation was chosen as the demonstration platform. Obstacles encountered in obtaining better performance, by using the selected hardware are also presented. Author

A93-20701 National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HIGH-PERFORMANCE COMPUTING FOR FLIGHT VEHICLES; PROCEEDINGS OF THE SYMPOSIUM, WASHINGTON, DEC. 7-9, 1992
AHMED K. NOOR, ED. (Virginia Univ.; NASA, Langley Research Center, Hampton, VA) and SAMUEL L. VENNERI, ED. (NASA, Space Research Div., Washington) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 553 p.
Copyright
The present conference discusses high-performance computing systems for flight vehicles, large-scale simulations on high-performance flight computers and software, multidisciplinary and design/optimization applications of computers, computational electromagnetics and acoustics, the simulation of aircraft powerplant turbomachinery and reacting flows, and flow calculations on parallel machines. Also discussed are direct flow simulation Monte Carlo methods, structural mechanics sensitivity and fracture calculations on parallel machines, grid-generation and advanced algorithms for CFD, advanced solid-mechanics and structures applications, and advancements in flow visualization technology and neural networks. (For individual items see A93-20702 to A93-20751) O.C.

A93-20708
ISSUES IN LARGE-SCALE OPTIMIZATION WITH EXPENSIVE FUNCTIONS
M. H. WRIGHT (AT&T Bell Labs., Murray Hill, NJ) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 53-61. refs
Copyright
The use of sequential quadratic programming (SQP) methods in flight-vehicle optimization problems is presently taken to be paradigmatic of progress to date in solving large-scale problems with expensive function evaluations. Specialized SQP method are undergoing very promising algorithmic developments; as modeling language and automatic differentiation systems become more sophisticated, constrained optimization problems of extreme sophistication and large dimension can be solved almost interactively, in a tailored environment. O.C.

A93-20711* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
MULTIDISCIPLINARY COMPUTATIONAL AEROSCIENCES
P. KUTLER (NASA, Ames Research Center, Moffett Field, CA) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 87-95. refs
Copyright
By combining CFD with the computational state-of-the-art in structural mechanics, propulsion, aeroacoustics, electromagnetics, etc., multidisciplinary computational aerosciences (MCAS) poses a formidable computational challenge requiring the use of massively parallel machines. Research efforts must accordingly be directed to three areas: (1) parallel architectures, (2) systems software, and (3) applications software; attention is presently given to the last of these, in view of developments at NASA-Ames in solution methodology, physical modeling, and multidisciplinary validation experiments. O.C.

A93-20739
LARGE-SCALE SIMULATION OF THE THREE-DIMENSIONAL NAVIER-STOKES EQUATIONS
D. D. CLINE and J. A. SCHUTT (Sandia National Labs., Albuquerque, NM) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 423-428. refs
(Contract DE-AC04-76DP-00789)
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An account is given of a Navier-Stokes solver that can simulate 3D, time-dependent fluid flow on a massively parallel MIMD computer. Solutions are given for a 3D extension of the classical Rayleigh problem for natural convection, together with the solutions for 3D Kelvin-Helmholtz instabilities on 8.4 million grid cells, using 1024 processors which make available 4 Gbytes of memory. Both primary and secondary vortex structures are in clear evidence. O.C.

A93-20740
NEWTON-LIKE METHODS FOR FAST HIGH RESOLUTION SIMULATION OF HYPERSONIC VISCOUS FLOWS
N. QIN, X. XU, and B. E. RICHARDS (Glasgow Univ., United Kingdom) Computing Systems in Engineering (ISSN 0956-0521) vol. 3, no. 1-4 1992 p. 429-435. Research supported by Univ. of Glasgow refs
(Contract SERC-GR/E/89056)
Copyright
Two Newton-like methods, i.e., the sparse finite difference Newton method and the sparse quasi-Newton method, are applied to the Navier-Stokes solutions of hypersonic flows using the Osher flux difference splitting high resolution scheme. The resulting large block structured sparse linear system is solved by a new multilevel iterative solver, the alpha-GMRES method, which includes a preconditioner and a damping factor. The algorithm is demonstrated to provide fast, accurate solutions of the hypersonic flow over a cone at high angle of attack. Being parallelizable on distributed memory multiprocessors and having an ability to tackle nonlinear problems, it has great promise in tackling more complex practical air vehicle configurations. Author

A93-21868
SIMULATION IN AERONAUTICS [LA MODELISATION EN AERONAUTIQUE]
PIERRE PERRIER (Academie des Sciences, Inst. de France, Paris) Revue Scientifique et Technique de la Defense (ISSN 0994-1541) no. 18 4th Quarter, 1992 p. 115-119. In French.
Copyright
It is pointed out that numerical simulation is a powerful tool for the design of new aerospace vehicles, as well as a very efficient modeling tool for the realization and operation of such vehicles. Numerous spinoffs are expected in other fields as well, but the size of the teams involved and the computing capabilities are the current limitations for a more extended use of numerical simulations. Numerical simulation methodology is briefly examined; the use of simulation in industry is discussed; and aeronautical simulation in France and elsewhere is briefly considered. L.M.

A93-22132
MIST - A REMOTE BRIEFING SYSTEM
P. J. STEVENS (Meteorological Office, Bracknell, United Kingdom) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 139-143. refs
Copyright
The concept of MIST, a remote briefing system, is presented within the framework of the efforts of the U.K. Meteorological Office to deliver perishable data and information to the varied customers it supports. The system is simple, user-friendly, visually attractive, and inexpensive. It can be tailored to display almost any type of data, both textual and graphical. The system architecture can be changed to support different inputs and outputs: it is possible to have multiple screens driven by one CPU displaying and updating information covering, e.g., different areas of the world. P.D.

A93-22163* National Aeronautics and Space Administration, Washington, DC.

A MICROCOMPUTER PROGRAM FOR ESTIMATING LOW ALTITUDE WIND AND TURBULENCE FIELDS

F. L. LUDWIG and PETER LESTER (San Jose State Univ., CA) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 295-300. Research supported by U.S. Army, USAF, NASA, et al refs

Copyright

Past efforts to develop methods for objective wind analysis and to provide turbulence estimates to pilots are reviewed. The present approach involves a wind module and a turbulence module. The wind module extends the critical dividing streamline concept and past developments in mass-conserving wind interpolation schemes. The turbulence module is based on recent efforts to develop practical atmospheric turbulence parameterization schemes based on lapse rate, wind shear, surface heating, and surface roughness. The lapse rate and wind shear are readily obtained from the wind module. Surface roughness and heating come from land use information and net radiation estimates derived from cloud cover, terrain slope, local time, and latitude. This system is argued to have considerable potential for providing useful online information for many kinds of aircraft operations. P.D.

A93-22302*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.

ON SOME RECENT ADVANCES IN MULTIDISCIPLINARY ANALYSIS OF HYPERSONIC VEHICLES

K. K. GUPTA, K. L. PETERSEN (NASA, Flight Research Center, Edwards, CA), and C. L. LAWSON (Eloret Inst., Claremont, CA) Dec. 1992 9 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs

(AIAA PAPER 92-5026) Copyright

This paper presents pertinent details of the development and application of an integrated, multidisciplinary finite element analysis tool for the effective modeling and simulation of aerospace vehicles including hypersonic ones. Recent advances in this connection include more efficient CFD solution techniques and also aeroservoelastic stability analysis methods that employ unsteady aerodynamic forces for computation of flutter and divergence speeds. An accelerated Euler solution procedure based on the Aitken acceleration technique has recently been implemented that effects considerable improvement in solution efficiency for the same level of solution accuracy, as evidenced by example problems presented in the paper. A summary of finite element numerical formulations for the various individual disciplines as well as for the unified aeroservoelastic analysis and some relevant numerical examples are also presented in the paper. Author

A93-22337*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

DEVELOPMENT AND APPLICATION OF GASP 2.0

W. D. MCGRORY (AeroSoft, Inc., Blacksburg, VA), L. D. HUEBNER (NASA, Langley Research Center, Hampton, VA), D. C. SLACK (AeroSoft, Inc., Blacksburg, VA), and R. W. WALTERS (AeroSoft, Inc.; Virginia Polytechnic Inst. and State Univ., Blacksburg) Dec. 1992 12 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs

(AIAA PAPER 92-5067) Copyright

GASP 2.0 represents a major new release of the computational fluid dynamics code in wide use by the aerospace community. The authors have spent the last two years analyzing the strengths and weaknesses of the previous version of the finite-rate chemistry, Navier Stokes solution algorithm. What has resulted is a completely redesigned computer code that offers two to four times the performance of previous versions while requiring as little as one quarter of the memory requirements. In addition to the improvements in efficiency over the original code, Version 2.0 contains many new features. A brief discussion of the improvements made to GASP, and an application using GASP 2.0 which demonstrates some of the new features are presented. Author

A93-22540

DAMAGE DETECTION IN SMART STRUCTURES USING NEURAL NETWORKS AND FINITE-ELEMENT ANALYSES

J. N. KUDVA, N. MUNIR, and P. W. TAN (Northrop Corp., Hawthorne, CA) Smart Materials and Structures (ISSN 0964-1726) vol. 1, no. 2 June 1992 p. 108-112. refs

Copyright

An important aspect of the smart structures concept is the automated structural health monitoring of aircraft structures. This requires detecting damage and assessing its effect on structural performance. This paper presents a new approach to detecting and defining large area damage on a structure. The approach is based on using a neural network to deduce the damage size and location from measured strain values at discrete locations. The neural network is trained using results from finite-element analyses. Several examples illustrating this approach are presented. Author

A93-22604*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

LEWICE DROPLET TRAJECTORY CALCULATIONS ON A PARALLEL COMPUTER

STEVEN C. CARUSO (Nielsen Engineering & Research, Inc., Mountain View, CA) Jan. 1993 12 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(Contract NAS3-26321)

(AIAA PAPER 93-0172) Copyright

A parallel computer implementation (128 processors) of LEWICE, a NASA Lewis code used to predict the time-dependent ice accretion process for two-dimensional aerodynamic bodies of simple geometries, is described. Two-dimensional parallel droplet trajectory calculations are performed to demonstrate the potential benefits of applying parallel processing to ice accretion analysis. Parallel performance is evaluated as a function of the number of trajectories and the number of processors. For comparison, similar trajectory calculations are performed on single-processor Cray computers, and the best parallel results are found to be 33 and 23 times faster, respectively, than those of the Cray XMP and YMP. V.L.

A93-22639#

AIRCRAFT GRID GENERATION USING INTERACTIVE ENVIRONMENT

LIH-YENN ONG and KUOK-MING LEE (Singapore Aerospace, Ltd., Singapore) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by National Science and Technology Board of Singapore refs

(AIAA PAPER 93-0224) Copyright

The development of an interactive grid generation system is being presented. The aim of this work is to employ the power of computer graphics to generate multi-block structured grids used in solving the Euler and Navier Stokes equations. The work encompasses the formulation of a grid generation approach, design of the display modes and construction of the graphical user interfaces. The implementation is carried out on a Silicon Graphics Personal Iris workstation using the GL library. Author

A93-22830

ROBUST STABILIZATION BASED ON TOPOLOGICAL CONNECTEDNESS

RONALD A. PEREZ (Wisconsin Univ., Milwaukee), OSITA D. I. NWOKAH, and DZU K. LE (Purdue Univ., West Lafayette, IN) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 1 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 796, 797. refs

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Easily computable graphical conditions are presented under which the stabilizability of a given nominal plant implies the stabilizability of every plant in the set. These conditions should be very helpful in the design of robust multivariable controllers. C.D.

A93-22854
EXTENDED LINEAR QUADRATIC GAUSSIAN CONTROL UNDER RANDOMLY VARYING DISTRIBUTED DELAYS
ASOK RAY, LUEN-WOEI LIOU, and NAN-CHYUAN TSAI (Pennsylvania State Univ., University Park) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1084-1088. refs
(Contract N00014-90-J-1513)
Copyright

The authors present a unified estimation and control methodology for compensation of randomly varying distributed delays in the stochastic setting, called the extended linear quadratic Gaussian (ELQG) control. Although the certainty equivalence property of LQG does not hold for ELQG in general, the combined state estimation and state feedback approach of ELQG offers a suboptimal solution to control of randomly delayed processes. Specifically, ELQG is applicable to analysis and synthesis of integrated communication and control systems (ICCS) for vehicle management of future generation aircraft and autonomous vehicles where a computer network is employed for distributed processing and on-line information exchange between diverse control and decision-making functions. Results of simulation experiments are presented to demonstrate the efficacy of the ELQG algorithm for flight control of an advanced aircraft. I.E.

A93-22855
DISCRETE-TIME LTR SYNTHESIS OF DELAYED CONTROL SYSTEMS
JENNY H. SHEN and ASOK RAY (Pennsylvania State Univ., University Park) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1102-1106. refs
(Contract N00014-90-J-1513)
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The authors focus on robust compensation of delays within a multi-input multi-output discrete-time feedback loop for application to real-time distributed control systems. The delay compensation algorithm, formulated here, is an extension of the standard loop transfer recovery procedure from one-step prediction to the general case of p-step prediction. It is shown that the steady-state minimum-variance filter gain is the H2-minimization solution of the relative error between the target sensitivity matrix and the actual sensitivity matrix for p-step prediction. This concept forms the basis for synthesis of robust p-step delay compensators. The proposed control synthesis procedure for delay compensation is demonstrated via simulation of the flight control system of an advanced aircraft. I.E.

A93-22899
A MULTISENSOR-MULTITARGET DATA ASSOCIATION ALGORITHM FOR HETEROGENEOUS SENSORS
SOMNATH DEB, KRISHNA R. PATTIPATI, and YAAKOV BAR-SHALOM (Connecticut Univ., Storrs) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 1779-1783. refs
(Contract AF-AFOSR-91-0242; N00014-91-J-1950)
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The authors present an algorithm to solve the static problem of associating data from three spatially distributed heterogeneous sensors, each with a set of detections at the same time. The sensors could be active or passive. The source of a detection can be either a real target, in which case the measurement is the true observation variable of the target plus measurement noise, or a spurious one, i.e., a false alarm. In addition, the sensors may have nonunity detection probabilities. The problem is to associate the measurements from the sensors to identify the real targets, and to obtain their position estimates. Mathematically, this measurement-target association problem leads to a generalized three-dimensional matching problem, which is known to be NP-hard. A fast, but near-optimal 3-D matching algorithm is presented suited for estimating the positions of a large number of targets in a dense cluster for real-time applications. Performance results on several representative test cases solved by the algorithm are presented. I.E.

A93-22926
PERFORMANCE PREDICTION OF THE INTERACTING MULTIPLE MODEL ALGORITHM
X. R. LI and YAAKOV BAR-SHALOM (Connecticut Univ., Storrs) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 3 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 2109-2113. refs
(Contract N00014-91-J-1950; NSF ECS-91-09962)
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An effective approach to nonsimulation performance prediction of the interacting multiple model algorithm is presented. This approach is based on a stochastic performance measure (i.e., conditional expectation of the error covariance) of hybrid nature in the sense that it is a continuous-valued matrix function of a discrete-valued sequence-the system mode sequence. This system mode sequence is an essential description of the scenario of the problem on which the performance of the algorithm is dependent and being predicted. The performance measure is efficiently calculated in an offline recursion. The capability of this approach in predicting quantitatively the average performance of the algorithm is illustrated via two important examples: a generic air traffic control tracking problem and a nonstationary noise identification problem. The predicted performance given by this approach agrees remarkably well with the simulated one, which verifies the good accuracy of the approach. I.E.

A93-22968
OUTPUT TRACKING CONTROL OF NONLINEAR SYSTEMS WITH WEAKLY NON-MINIMUM PHASE
KUANG-YOW LIAN, LI-CHEN FU (National Taiwan Univ., Taipei), and TEH-LU LIAO (National Cheng Kung Univ., Tainan, Taiwan) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 4 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 3081-3085. refs
(Contract NSC-79-0404-E002-03)
Copyright

The authors consider the problem of designing a robust output tracking controller for MIMO (multiple-input multiple-output) nonlinear systems with weakly nonminimum phase. Based on their system formulation, control plants with uncertainties and/or with actuator dynamics fall into the class under consideration. Under some mild assumptions, it is shown that the overall states and the tracking errors are uniformly bounded. Furthermore, the tracking errors converge to a small residual set. I.E.

A93-22971
PARAMETER OPTIMIZATION FOR AN H2 PROBLEM WITH MULTIVARIABLE GAIN AND PHASE MARGIN CONSTRAINTS
WON-ZON CHEN (U.S. Naval Postgraduate School, Monterey, CA) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 4 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 3124-3129. refs
Copyright

The author presents a parameter optimization approach that adopts a typical frequency-shaped LQG (linear quadratic Gaussian) control structure in which the feedback and observer gains are optimized simultaneously. The acute robustness problems arising from using the standard LQR/LTR (linear quadratic regulator/loop transfer recovery) method for some H2 problems can be effectively solved by incorporating 'principal region based' multivariable gain and phase margin constraints in the optimization process. The undue conservatism of using singular values alone is alleviated since both gain and phase information are considered. An MIMO (multiple-input multiple-output) flight control problem for an unstable aircraft is used to illustrate the design approach and demonstrate its effectiveness. I.E.

A93-22978
SEQUENTIAL SMOOTHING AND FILTERING FOR MANEUVERING TARGET TRACKING
JAMES R. CLOUTIER (USAF, Wright Lab., Eglin AFB, FL), CHUN YANG, and CHING-FANG LIN (American GNC Corp., Chatsworth, CA) *In* 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 4 Piscataway, NJ Institute of Electrical and Electronics Engineers 1992 p. 3236-3241. refs
(Contract F08630-91-C-0030)
Copyright

Maneuvering target estimation is considered. Measurement concatenation has been used as an approach to handle rapidly sampled measurements and to reap the benefits of combined filtering and smoothing within the same estimation interval. Various aspects of the maneuvering model-based smoothing and filtering algorithm (SFA) have been investigated, and simulation results show the improvement in estimation gained. In particular, various techniques have been used to combine the nonmaneuver model-based SFA and the maneuver model-based SFA. It has been seen that tradeoffs are required to achieve the best tracking performance for both the quiescent and excitation periods at the expense of algorithmic complexity and computational burden. I.E.

A93-23326#
A RE-EVALUATION OF THE WAVERIDER DESIGN PROCESS
DAVID W. BURNETT (McDonnell Douglas Corp., Huntington Beach, CA) and MARK J. LEWIS (Maryland Univ., College Park) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research sponsored by McDonnell Douglas Space Systems Co., U.S. Navy, and USAF refs
(AIAA PAPER 93-0404) Copyright

The University of Maryland has developed the Maryland Axisymmetric Waverider Program (MAXWARP) code that defines waverider configurations based on point solutions for conic and power-law flowfields. Lessons learned in using MAXWARP to generate a waverider solution and the transfer of this design to a CAD/CAM system for utilization in higher-order codes and/or model fabrication are discussed. Waverider technology is shown to offer a great potential for advanced aerodynamic efficiency over a wide range of mission scenarios. R.E.P.

A93-23330*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN APPLICATION OF ARTIFICIAL NEURAL NETWORKS TO EXPERIMENTAL DATA APPROXIMATION
ANDREW J. MEADE, JR. (Rice Univ., Houston, TX) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(Contract NAG1-1433)
(AIAA PAPER 93-0408) Copyright

As an initial step in the evaluation of networks, a feedforward architecture is trained to approximate experimental data by the backpropagation algorithm. Several drawbacks were detected and an alternative learning algorithm was then developed to partially address the drawbacks. This noniterative algorithm has a number of advantages over the backpropagation method and is easily implemented on existing hardware. R.E.P.

A93-23699# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A GRAPHICAL USER-INTERFACE FOR PROPULSION SYSTEM ANALYSIS
BRIAN P. CURLETT (NASA, Lewis Research Center, Cleveland, OH) and KATHLEEN RYALL (Harvard Univ., Cambridge, MA) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N92-33894 refs
(Contract RTOP 505-69-50)
(AIAA PAPER 93-0223) Copyright

NASA LeRC uses a series of computer codes to calculate installed propulsion system performance and weight. The need to evaluate more advanced engine concepts with a greater degree of accuracy has resulted in an increase in complexity of this analysis system. Therefore, a graphical user interface was developed to allow the analyst to more quickly and easily apply these codes. The development of this interface and the rationale for the approach taken are described. The interface consists of a method of pictorially representing and editing the propulsion system configuration, forms for entering numerical data, on-line help and documentation, post processing of data, and a menu system to control execution. Author

N93-16288# Alenia Spazio S.p.A., Naples (Italy). Tecnologia del Volo, Aerodinamica.
AN ADVANCED GRAPHICS-INTERACTIVE SYSTEM FOR A MULTI-BLOCK STRUCTURED GRID GENERATION WITHIN AN INDUSTRIAL ENVIRONMENT
A. AMENDOLA, R. TOGNACCINI, and P. L. VITAGLIANO 1991 12 p
(ETN-92-92885) Avail: CASI HC A03/MF A01

A grid generation procedure embedded in a flow simulation system suitable for the analysis of a complex aerodynamic shape like an aircraft is described. The procedure is based on a multiblock approach and incorporates new technical concepts like discontinuous grid lines across block boundaries, local grid refinement, unstructured blocks packing, hyperblocks, zonal flow models. These improvements are aimed at increasing the system flexibility and easing the manipulation of complicated configurations while at the same time enhancing flow simulation accuracy. The complexity of the system is very high, but the required user effort is made realistic by the extensive applications of graphic interactive tools. It is pointed out that preliminary tasks like geometry modeling and domain decomposition are the actual critical items within the overall grid generation process. ESA

N93-16500# Mei Associates, Inc., San Antonio, TX.
FUNCTIONAL REQUIREMENTS OF AN ADVANCED INSTRUCTIONAL DESIGN ADVISOR: SIMULATION AUTHORING, VOLUME 3 Interim Report, Mar. 1990 - Feb. 1991
M. D. MERRILL, MARK K. JONES, DOUGLAS M. TOWNE, and EARL R. NASON Sep. 1992 131 p Prepared in cooperation with Utah State Univ., Logan and University of Southern California, Los Angeles
(Contract F33615-88-C-0003)
(AD-A256650; AL-TP-1992-0035-VOL-3) Avail: CASI HC A07/MF A02

The Advanced Instructional Design Advisor (AIDA) will provide automated and intelligent assistance to inexperienced instructional computer-based instructional developers. Two reports are presented which discuss simulation capability and AIDA. First, Drs. M. David Merrill and Mark K. Jones describe the integration of transaction shells (TAX) with RAPIDS, a simulation-based instructional authoring and delivery system. They argue RAPIDS could be used to build simulations and some portions of the knowledge representation model required by AIDA. Merrill and Jones present an example of the instructional design process using the AIDA transaction shells. Then, Dr. Douglas Towne discusses the instructional development process using the RAPIDS system. Towne describes specifying course structure, building device simulations, producing simulations and delivering instruction using RAPIDS. He walks through the RAPIDS instructional development process using instruction on the maintenance of the U.S. Air Force T-38 jet aircraft as an example. Two significant conclusions resulted from this work. First, incorporating RAPIDS into the AIDA experimental prototype (AIDA) would be too costly and time-consuming. Second, because AIDA does require some simulation creation capability, a simpler simulation authoring capability will be included in the near term version of the system. GRA

N93-16515# Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany). Abteilung Steuerung and Regelung.

A CONTRIBUTION TO THE DYNAMIC FEEDFORWARD OPEN LOOP CONTROL OF MULTIVARIABLE SYSTEMS AND TO THE OPTIMAL DESIGN OF COMMAND FUNCTIONS [EIN BEITRAG ZUR DYNAMISCHEN VORSTEUERUNG VON MEHRGROEBENSYSTEMEN UND ZUR OPTIMALEN GESTALTUNG VON FUEHRUNGSFUNKTIONEN]

HAGEN LEYENDECKER Feb. 1992 67 p In GERMAN (ISSN 0939-2963)

(DLR-FB-92-05; ETN-93-92401) Avail: CASI HC A04/MF A01; DLR, Wissenschaftliches Berichtswesen, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Germany, HC

The analysis of the dynamic feedforward open loop control system realized by the model of the plant gives information about the conditions of the command functions to fulfilled so that the plant can follow these commands without return difference. Unstable eigenvalues of the feedforward open loop controller are not acceptable. They have to be compensated by nominator zeros of the transfer functions of the command inputs. Two examples and flight test results of a maneuver demand system for the BO-105 helicopter show the efficiency of the control concept in practice. ESA

N93-16567# Technische Univ., Delft (Netherlands).

DEVELOPMENT OF A COMPUTER ASSISTED TOOLBOX FOR AERODYNAMIC DESIGN OF AIRCRAFT AT SUBCRITICAL CONDITIONS WITH APPLICATION TO THREE-SURFACE AND CANARD AIRCRAFT Ph.D. Thesis

JAN MIDDEL 1992 266 p

(ISBN-90-6275-768-5; ETN-92-92795) Copyright Avail: CASI HC A12/MF A03

The following are considered: the implementation, extension and adaptation of a panel method, important tools used in the aerodynamic monodiscipline, to the conceptual/preliminary design environment, as well as application to the three surace aircraft concept. The tools developed and the application of these tools to the investigation of the three surface aircraft are described. The development of preliminary design systems in general and the Aircraft Design and Analysis System (ADAS) in particular, are considered. The requirements for a numerical aerodynamic toolbox are identified and discussed. The theoretical backgrounds and hence the scope and restrictions concerning the applicability of the ADAS aerodynamic module are discussed. All aerodynamics utilities are built around the NLRAERO program. The capabilities and scope of the original code were increased. The core was adapted to accommodate typical ADAS capabilities such as design optimization and variation. Focus is on drag, lift and pitching moment considerations of a whole series of aircraft, with a not yet fully determined geometry. This required design and implementation of automatic grid generation, more accurate drag and lift analysis as well as implementation of some inverse (optimization, design) capabilities. The three surface aircraft concept as an alternative to the conventional and canard configuration was studied. Aerodynamic trimmed cruise performances were studied for a family of aircraft, through the application of the ADAS Aerodynamic module to both design and off design conditions. ESA

N93-16613*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

USER'S MANUAL FOR INTERACTIVE DATA DISPLAY SYSTEM (IDDS)

JAMES D. STEGEMAN Nov. 1992 43 p Original contains color illustrations

(Contract RTOP 505-62-52)

(NASA-TM-105572; E-6897; NAS 1.15:105572) Avail: CASI HC A03/MF A01; 5 functional color pages

A computer graphics package for the visualization of three-dimensional flow in turbomachinery has been developed and tested. This graphics package, called IDDS (Interactive Data Display System), is able to 'unwrap' the volumetric data cone associated with a centrifugal compressor and display the results in an easy to understand two-dimensional manner. IDDS will provide the majority of the visualization and analysis capability for the ICE (Integrated CFD and Experiment) system. This document is intended to serve as a user's manual for IDDS in a stand-alone mode. Currently, IDDS is capable of plotting two- or three-dimensional simulation data, but work is under way to expand IDDS so that experimental data can be accepted, plotted, and compared with a simulation dataset of the actual hardware being tested. Author

N93-16763*# University of South Florida, Tampa. Dept. of Civil Engineering and Mechanics.

THE ROLE OF UNDER-DETERMINED APPROXIMATIONS IN ENGINEERING AND SCIENCE APPLICATION

WILLIAM C. CARPENTER *In* Hampton Univ., NASA/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program 1992 p 79-86 Sep. 1992

Avail: CASI HC A02/MF A03

There is currently a great deal of interest in using response surfaces in the optimization of aircraft performance. The objective function and/or constraint equations involved in these optimization problems may come from numerous disciplines such as structures, aerodynamics, environmental engineering, etc. In each of these disciplines, the mathematical complexity of the governing equations usually dictates that numerical results be obtained from large computer programs such as a finite element method program. Thus, when performing optimization studies, response surfaces are a convenient way of transferring information from the various disciplines to the optimization algorithm as opposed to bringing all the sundry computer programs together in a massive computer code. Response surfaces offer another advantage in the optimization of aircraft structures. A characteristic of these types of optimization problems is that evaluation of the objective function and response equations (referred to as a functional evaluation) can be very expensive in a computational sense. Because of the computational expense in obtaining functional evaluations, the present study was undertaken to investigate under-determinined approximations. An under-determined approximation is one in which there are fewer training pairs (pieces of information about a function) than there are undetermined parameters (coefficients or weights) associated with the approximation. Both polynomial approximations and neural net approximations were examined. Three main example problems were investigated: (1) a function of one design variable was considered; (2) a function of two design variables was considered; and (3) a 35 bar truss with 4 design variables was considered. Author

N93-17172*# National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.

SOFTWARE ENGINEERING LABORATORY ADA PERFORMANCE STUDY: RESULTS AND IMPLICATIONS

ERIC W. BOOTH (Computer Sciences Corp., Lanham, MD.) and MICHAEL E. STARK *In its* Collected Software Engineering Papers, Volume 10 9 p Nov. 1992

Avail: CASI HC A02/MF A02

The SEL is an organization sponsored by NASA/GSFC to investigate the effectiveness of software engineering technologies applied to the development of applications software. The SEL was created in 1977 and has three organizational members: NASA/GSFC, Systems Development Branch; The University of Maryland, Computer Sciences Department; and Computer Sciences Corporation, Systems Development Operation. The goals of the SEL are as follows: (1) to understand the software development process in the GSFC environments; (2) to measure the effect of various methodologies, tools, and models on this process; and (3) to identify and then to apply successful development practices. The activities, findings, and recommendations of the SEL are recorded in the Software Engineering Laboratory Series, a continuing series of reports that include the Ada Performance Study Report. This paper describes the background of Ada in the Flight Dynamics Division (FDD), the objectives and scope of the Ada

Performance Study, the measurement approach used, the performance tests performed, the major test results, and the implications for future FDD Ada development efforts. Author

N93-17305*# Bronx Community Coll., NY. Dept. of Engineering Technologies.

USING SOFTWARE METRICS AND SOFTWARE RELIABILITY MODELS TO ATTAIN ACCEPTABLE QUALITY SOFTWARE FOR FLIGHT AND GROUND SUPPORT SOFTWARE FOR AVIONIC SYSTEMS

STELLA LAWRENCE *In* Alabama Univ., 1992 NASA/ASEE Summer Faculty Fellowship Program 6 p Dec. 1992
Avail: CASI HC A02/MF A03

This paper is concerned with methods of measuring and developing quality software. Reliable flight and ground support software is a highly important factor in the successful operation of the space shuttle program. Reliability is probably the most important of the characteristics inherent in the concept of 'software quality'. It is the probability of failure free operation of a computer program for a specified time and environment. Author

N93-17517*# McDonnell Aircraft Co., Saint Louis, MO.

DOMAIN SPECIFIC SOFTWARE DESIGN FOR DECISION AIDING

KIRBY KELLER and KEVIN STANLEY *In* NASA. Ames Research Center, Working Notes from the 1992 AAAI Workshop on Automating Software Design. Theme: Domain Specific Software Design p 86-92 Jul. 1992
Avail: CASI HC A02/MF A02

McDonnell Aircraft Company (MCAIR) is involved in many large multi-discipline design and development efforts of tactical aircraft. These involve a number of design disciplines that must be coordinated to produce an integrated design and a successful product. Our interpretation of a domain specific software design (DSSD) is that of a representation or framework that is specialized to support a limited problem domain. A DSSD is an abstract software design that is shaped by the problem characteristics. This parallels the theme of object-oriented analysis and design of letting the problem model directly drive the design. The DSSD concept extends the notion of software reusability to include representations or frameworks. It supports the entire software life cycle and specifically leads to improved prototyping capability, supports system integration, and promotes reuse of software designs and supporting frameworks. The example presented in this paper is the task network architecture or design which was developed for the MCAIR Pilot's Associate program. The task network concept supported both module development and system integration within the domain of operator decision aiding. It is presented as an instance where a software design exhibited many of the attributes associated with DSSD concept. Author

N93-17522*# Michigan State Univ., East Lansing.

A DOMAIN-SPECIFIC DESIGN ARCHITECTURE FOR COMPOSITE MATERIAL DESIGN AND AIRCRAFT PART REDESIGN

W. F. PUNCH, III, K. J. KELLER, W. BOND (McDonnell Aircraft Co., Saint Louis, MO.), and J. STICKLEN (Michigan State Univ., East Lansing.) *In* NASA. Ames Research Center, Working Notes from the 1992 AAAI Workshop on Automating Software Design. Theme: Domain Specific Software Design p 115-120 Jul. 1992
Avail: CASI HC A02/MF A02

Advanced composites have been targeted as a 'leapfrog' technology that would provide a unique global competitive position for U.S. industry. Composites are unique in the requirements for an integrated approach to designing, manufacturing, and marketing of products developed utilizing the new materials of construction. Numerous studies extending across the entire economic spectrum of the United States from aerospace to military to durable goods have identified composites as a 'key' technology. In general there have been two approaches to composite construction: build models of a given composite materials, then determine characteristics of the material via numerical simulation and empirical testing; and experience-directed construction of fabrication plans for building composites with given properties. The first route sets a goal to capture basic understanding of a device (the composite) by use of a rigorous mathematical model; the second attempts to capture the expertise about the process of fabricating a composite (to date) at a surface level typically expressed in a rule based system. From an AI perspective, these two research lines are attacking distinctly different problems, and both tracks have current limitations. The mathematical modeling approach has yielded a wealth of data but a large number of simplifying assumptions are needed to make numerical simulation tractable. Likewise, although surface level expertise about how to build a particular composite may yield important results, recent trends in the KBS area are towards augmenting surface level problem solving with deeper level knowledge. Many of the relative advantages of composites, e.g., the strength:weight ratio, is most prominent when the entire component is designed as a unitary piece. The bottleneck in undertaking such unitary design lies in the difficulty of the re-design task. Designing the fabrication protocols for a complex-shaped, thick section composite are currently very difficult. It is in fact this difficulty that our research will address. Author

N93-18332*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

APPLICATION OF A NEURAL NETWORK AS A POTENTIAL AID IN PREDICTING NTF PUMP FAILURE

JAMES L. ROGERS, JEFFREY S. HILL, WILLIAM J. LAMARSH, II (Unisys Corp., Hampton, VA.), and DAVID E. BRADLEY Jan. 1993 12 p
(Contract RTOP 505-63-50-06)
(NASA-TM-107667; NAS 1.15:107667) Avail: CASI HC A03/MF A01

The National Transonic Facility has three centrifugal multi-stage pumps to supply liquid nitrogen to the wind tunnel. Pump reliability is critical to facility operation and test capability. A highly desirable goal is to be able to detect a pump rotating component problem as early as possible during normal operation and avoid serious damage to other pump components. If a problem is detected before serious damage occurs, the repair cost and downtime could be reduced significantly. A neural network-based tool was developed for monitoring pump performance and aiding in predicting pump failure. Once trained, neural networks can rapidly process many combinations of input values other than those used for training to approximate previously unknown output values. This neural network was applied to establish relationships among the critical frequencies and aid in predicting failures. Training pairs were developed from frequency scans from typical tunnel operations. After training, various combinations of critical pump frequencies were propagated through the neural network. The approximated output was used to create a contour plot depicting the relationships of the input frequencies to the output pump frequency. Author

N93-18372*# Calspan-State Univ. of New York Joint Venture, Buffalo, NY.

THEORETICAL CONSTRAINTS IN THE DESIGN OF MULTIVARIABLE CONTROL SYSTEMS Final Report, Jan. 1993

E. G. RYNASKI and D. J. MOOK Jan. 1993 46 p
(Contract NAG1-1361)
(NASA-CR-191900; NAS 1.26:191900) Avail: CASI HC A03/MF A01

The theoretical constraints inherent in the design of multivariable control systems were defined and investigated. These constraints are manifested by the system transmission zeros that limit or bound the areas in which closed loop poles and individual transfer function zeros may be placed. These constraints were investigated primarily in the context of system decoupling or non-interaction. It was proven that decoupling requires the placement of closed loop poles at the system transmission zeros. Therefore, the system transmission zeros must be minimum phase to guarantee a stable decoupled system. Once decoupling has been accomplished, the remaining part of the system exhibits transmission zeros at infinity, so nearly complete design freedom is possible in terms of placing both poles and zeros of individual

closed loop transfer functions. A general, dynamic inversion model following system architecture was developed that encompasses both the implicit and explicit configuration. Robustness properties are developed along with other attributes of this type of system. Finally, a direct design is developed for the longitudinal-vertical degrees of freedom of aircraft motion to show how a direct lift flap can be used to improve the pitch-heave maneuvering coordination for enhanced flying qualities. Author

N93-18630# Technische Univ., Brunswick (Germany). Fakultaet fuer Maschinenbau und Elektrotechnik.
REALIZATION OF REAL TIME GRAPHICS IN VEHICLES WITH HIGH DYNAMIC MOTION Ph.D. Thesis [EIN BEITRAG ZUR REALISIERUNG VON ECHTZEIT-GRAPHIK IN FAHRZEUGEN MIT HOCHDYNAMISCHER BEWEGUNG]
KLAUS BAVENDIEK 1991 122 p In GERMAN
(ETN-93-92739) Avail: CASI HC A06/MF A02

A process to make interactive computer graphics more comfortable and fast for cockpit indicator systems, which allows the image representations to be programmed in a high level language with the use of the work station, is developed. Human visual acuity was examined to establish the image quality and dynamics requirements. For both onboard and ground vector oriented graphic systems the T800 transputer was chosen as a microprocessor to realize parallel data processing. A digital scanning pulse generator was used for conversion of images into corresponding voltages of the electrical flight instrument system, which computes the display lines with the Bresenham algorithm. The necessary memory capacity was achieved by means of several powerful arithmetic logic units connected in series following a pipeline concept. A real time simulation was written for an experimental aircraft and tested for a static image project from a computer aided design system. ESA

N93-18665*# Bull HN Italia, Milan. Direzione Sistemi Esperti.
SCHEDULING OF AN AIRCRAFT FLEET
MASSIMO PALTRINIERI, ALBERTO MOMIGLIANO, and FRANCO TORQUATI *In* NASA. Ames Research Center, Working Notes from the 1992 AAAI Spring Symposium on Practical Approaches to Scheduling and Planning p 25-29 May 1992
Avail: CASI HC A01/MF A02

Scheduling is the task of assigning resources to operations. When the resources are mobile vehicles, they describe routes through the served stations. To emphasize such aspect, this problem is usually referred to as the routing problem. In particular, if vehicles are aircraft and stations are airports, the problem is known as aircraft routing. This paper describes the solution to such a problem developed in OMAR (Operative Management of Aircraft Routing), a system implemented by Bull HN for Alitalia. In our approach, aircraft routing is viewed as a Constraint Satisfaction Problem. The solving strategy combines network consistency and tree search techniques. Author

N93-18686*# Chicago Univ., IL. Artificial Intelligence Lab.
IOPS ADVISOR: RESEARCH IN PROGRESS ON KNOWLEDGE-INTENSIVE METHODS FOR IRREGULAR OPERATIONS AIRLINE SCHEDULING
JOHN E. BORSE and CHRISTOPHER C. OWENS *In* NASA. Ames Research Center, Working Notes from the 1992 AAAI Spring Symposium on Practical Approaches to Scheduling and Planning p 127-130 May 1992
Avail: CASI HC A01/MF A02

Our research focuses on the problem of recovering from perturbations in large-scale schedules, specifically on the ability of a human-machine partnership to dynamically modify an airline schedule in response to unanticipated disruptions. This task is characterized by massive interdependencies and a large space of possible actions. Our approach is to apply the following: qualitative, knowledge-intensive techniques relying on a memory of stereotypical failures and appropriate recoveries; and quantitative techniques drawn from the Operations Research community's work on scheduling. Our main scientific challenge is to represent schedules, failures, and repairs so as to make both sets of techniques applicable to the same data. This paper outlines ongoing research in which we are cooperating with United Airlines to develop our understanding of the scientific issues underlying the practicalities of dynamic, real-time schedule repair. Author

N93-18698# Technical Research Centre of Finland, Espoo. Ship Lab.
MOTION SIMULATION OF UNDERWATER VEHICLES
SEPPO KALSKE Apr. 1992 168 p Sponsored in part by Hollming Ltd.; Masa-Yards Ltd.; and Repola Ltd.
(ISSN 1235-0621)
(VTT-PUBS-97; ISBN-951-38-4075-1; ETN-93-93073) Copyright
Avail: CASI HC A08/MF A02

A three dimensional time domain simulation method for tethered subsea vehicle motions was developed. The method is applicable to vehicles equipped with thrusters as propulsion devices, and can be applied to vehicles of arbitrary shape. A computer program using the present method was written and is described in detail. Results are presented for one Remotely Operated Vehicle (ROV) with comparison of measured results from maneuvering tests in horizontal and vertical planes in a towing tank. The agreement between simulated and measured results is good in most cases. The effects of various input data quantities and differing thruster configurations were studied in additional simulations. ESA

N93-19112# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
IMPROVEMENTS TO LQGI/LTR METHODOLOGY FOR PLANTS WITH LIGHTLY DAMPED OR LOW FREQUENCY POLES M.S. Thesis
AN-CHI JU Dec. 1992 133 p
(AD-A258841; AFIT/GAE/ENY/92D-14) Avail: CASI HC A07/MF A02

The Linear Quadratic Gaussian/Loop Transfer Recovery (LQG/LTR) design has a tendency to invert the plant's dynamics, which is undesirable if there are plant poles near the imaginary axis. Static Output Feedback (SOF) is applied to reassign plant poles before LQG/LTR is applied. Alternatively, Robust Eigenstructure Assignment (REA) was used to design the target loop transfer function with an ideal eigenstructure to avoid the undesirable cancellations. Both methods were applied to several aircraft design problems. Results showed that the methods can be effectively used so that the LQG/LTR design has improved stability and performance; however, it was found that each method had strengths and weaknesses. GRA

N93-19338# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.
A MODEL FOR DETERMINING TASK SET SCHEDULABILITY IN THE PRESENCE OF SYSTEM EFFECTS M.S. Thesis
RUSTY O. BALDWIN Dec. 1992 261 p
(AD-A258915; AFIT/GCS/ENG/92D-02) Avail: CASI HC A12/MF A03

This research developed a parameterized model that accounts for system overhead and determines when an Ada runtime environment can no longer successfully execute a given Ada task set and still meet all deadlines. The Ada Compiler Evaluation Capability benchmark was used to characterize an actual runtime environment. Using that data, a generic model of a preemptive, rate monotonic priority based runtime system was developed which accounts for overhead due to clock updates, context switching, task suspension, and synchronization. Validation was based on the Hartstone benchmark. First, the benchmark was executed using, the actual runtime environment. Then, those results were compared with the execution of the benchmark using the model. In all cases, except one, the model predicted the point where the task set would fail. A runtime system optimization omitted from model caused the single failure. Experiments conducted using the model allowed the demonstration of the following results. System overhead can be modeled within the existing framework of rate monotonic scheduling theory. Runtime optimizations can be extremely sensitive to phase relationships between task periods

and workloads and can render a schedulable task set unschedulable. Requirements of the task set and the performance of the runtime system must be considered simultaneously. GRA

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PHYSICS

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

A93-18242
EXCITATION OF VELOCITY FLUCTUATIONS AND NOISE IN A WIND TUNNEL [VOZBUZHDENIE PUL'SATSII SKOROSTI I SHUMA V AERODINAMICHESKOI TRUBE]
V. A. VISHNIAKOV and A. G. PROZOROV Rossiiskaia Akademiia Nauk, Izvestiia, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 4 July-Aug. 1992 p. 165-172. In Russian. refs
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The sources of noise generation in wind tunnels are examined in the light of recent research in this field. An analysis of the available data suggests that noise in wind tunnels is generated by large-scale structures, both in the free jet and in the internal flow within the diffuser. This conclusion is consistent with the fact that, in some wind tunnels, a noticeable improvement has been achieved by moving perforation holes toward the end of the diffuser and increasing the distance between the perforations. V.L.

A93-19126
DGLR/AIAA AEROACOUSTICS CONFERENCE, 14TH, AACHEN, GERMANY, MAY 11-14, 1992, PROCEEDINGS. VOLS. 1 & 2
Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. Vol. 1, 527 p.; vol. 2, 500 p.
(DGLR BERICHT 92-03; ISBN 3-922010-68-7) Copyright
Topics presented include toward an integration of aerodynamics and aeroacoustics of rotors, boundary layer terms in high speed quadropole noise, experiments on the active control of boundary layer transition, boudary-layer induced noise in aircraft, and new design concepts for silencing aeroacoustic wind tunnels. Also presented are technical prospects for computational aeroacoustics, the spectral solution of acoustic boundary-value problems, noise from noncircular and high temperature jets, the noise from supersonic elliptic jets, and the numerical computation of steady-state acoustic disturbances in flow. (For individual items see A93-19127 to A93-19232) R.E.P.

A93-19136* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
COMPARISON OFDVANCED TURBOPROP INTERIOR NOISE CONTROL GROUND AND FLIGHT TEST DATA
MYLES A. SIMPSON and BOI N. TRAN (Douglas Aircraft Co., Long Beach, CA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 78-86. Previously announced in STAR as N91-31927 Research supported by McDonnell Douglas Corp. refs
(Contract NAS1-18037)
Interior noise ground tests conducted on a DC-9 aircraft test section are described. The objectives were to study ground test and analysis techniques for evaluating the effectiveness of interior noise control treatments for advanced turboprop aircraft, and to study the sensitivity of the ground test results to changes in various test conditions. Noise and vibration measurements were conducted under simulated advanced turboprop excitation, for two interior noise control treatment configurations. These ground measurement results were compared with results of earlier UHB (Ultra High Bypass) Demonstrator flight sts with comparable interior treatment configurations. The Demonstrator is an MD-80 test aircraft with the left JT8D engine replaced with a prototype UHB advanced turboprop engine. Author

A93-19137
BOUNDARY-LAYER INDUCED NOISE IN AIRCRAFT
W. R. GRAHAM (Cambridge Univ., United Kingdom) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 87-96. Research supported by British Aerospace (Regional Aircraft), Ltd refs
In order to investigate boundary-layer induced noise in aircraft, the excitation of a simply-supported flat plate by a turbulent undary layer is considered. Initially, the plate is bare, and t he well-known modal analysis for a fluid loaded panel applies. This analysis is used to investigate the acoustic power radiated by the plate, and its dependence on the parameters of the problem. It is found that alterations in structural damping, critical frequency and the degree of structural inhomogeneity affect the radiated power significantly, but that hydrodynamics coincidence effects are relatively unimportant. The model is then extended to include the effects of internal insulation and trim, by covering the plate and baffle surface with representative structural/acoustic elements. These are found to have an enormous modifying effect on the plate vibration and radiated sound, and a numerical study shows that, while the final three findings for the bare plate remain valid, the structural damping is now of greatly reduced importance. Author

A93-19138
CABIN NOISE SOURCE-PATH IDENTIFICATION FOR AD-200 ULTRALIGHT AIRCRAFT
ZHANGWEI HU, JIANPING YIN, and QIANG ZHANG (Nanjing Aeronautical Inst., China) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 97-101.
A new diagnostic method based on the two microphone cross spectral acoustic intensity technique was applied to identificate the cabin noise source paths. The simulating test using a loudspeaker and an electric-mechanical shaker to simulate the airborne and structureborne noise sources was conducted to prove the confidence of the proposed method. The results show that the discrepancy between measured and separated values of total average acoustic intensity level are respectively 1.7 dB(A) and 0.4 (A) for structureborne and airborne components, which is ac ceptable for engineering application. The static test with engine in operation shows that the airborne noise through the rear board of cabin is the dominant contributor to cabin noise. This is a reasonable result, which gives a guide to cabin noise control treatment. Author

A93-19139
SOUND TRANSMISSION THROUGH STIFFENED DOUBLE-PANEL STRUCTURES LINED WITH ELASTIC POROUS MATERIALS
GOPAL P. MATHUR, BOI N. TRAN (Douglas Aircraft Co., Long Beach, CA), J. S. BOLTON, and NAE-MING SHIAU (Purdue Univ., West Lafayette, IN) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 102-105. refs
This paper presents transmission loss prediction models for a periodically stiffened panel and stiffened double-panel structures using the periodic structure theory. The inter-panel cavity in the double-panels structures can be modeled as being separated by an airspace or filled with an elastic porous layer in various configurations. The acoustic behavior of elastic porous layer is described by a theory capable of accounting fully for multi-dimensional wave propagation in such materials. The predicted transmission loss of a single stiffened panel is compared with the measured data. Author

A93-19142
HELICOPTER MAIN ROTOR/TAIL ROTOR NOISE RADIATION CHARACTERISTICS FROM SCALED MODEL ROTOR EXPERIMENTS IN THE DNW
K.-J. SCHULTZ and W. R. SPLETTSTOESSER (DLR, Braunschweig, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 123-133. Research supported by BMVg and Bundesministerium fuer Verkehr refs

A wind tunnel study was performed to investigate the noise characteristics and directivity pattern of a 40 percent scaled helicopter rotor system (BO 105 main/tail rotor model). The major objectives of the study were to establish the importance of the tail rotor with respect to the overall noise radiation and to determine the noise reduction potential of aerodynamically improved blade design. The results show that under descent flight condition, where strong main rotor blade-vortex interaction occurs, the tail rotor contribution is of secondary order, while at climb condition the tail rotor dominates the noise radiation over a significant range of noise emission angles. Main-/tail-rotor aerodynamic interference noise does not appear to be a prime contributor to the total noise emission. The acoustic benefit from fully utilizing the potential of aerodynamically improved blade design was determined: maintaining rotor thrust while reducing the tip speed of such blades by 10 percent yielded noise reductions on the order of 3 to 4 dB and in certain directions in excess of 7 to 8 dB. Author

A93-19143* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ACOUSTIC FLIGHT TEST EXPERIENCE WITH THE XV-15 TILTROTOR AIRCRAFT WITH THE ADVANCED TECHNOLOGY BLADE (ATB)
DANNY R. HOAD, DAVID A. CONNER (NASA, Langley Research Center, Hampton, VA), and CHARLES K. RUTLEDGE (Lockheed Engineering and Sciences Co., Hampton, VA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 134-152. refs

An acoustic model that predicts the discrete frequency noise characteristics of helicopter rotors has been utilized in an analysis to help identify source characteristics. This technique incorporated a NASA Langley developed acoustic prediction technique, and a simplified flow field model to account for rotor wake reingestion in hover. The vehicle rotor system was modified to include the ATBs that were designed to provide for higher operating weights and improved maneuver load factor in helicopter and transition modes of operation. R.E.P.

A93-19147
NEW DESIGN CONCEPTS FOR SILENCING AEROACOUSTIC WIND TUNNELS
H. V. FUCHS, D. ECKOLDT (Fraunhofer-Inst. fuer Bauphysik, Stuttgart, Germany), U. ESSERS, and J. POTTHOFF (Forschungsinst. fuer Kraftfahrwesen und Fahrzeugmotoren, Stuttgart, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 177-186. refs

The vehicle wind tunnel at the University of Stuttgart is presently silenced so as to enable aeroacoustic testing both inside and outside the test objects at speeds up to 268 km/h. A novel silencer concept makes use of 'membrane absorbers' as extremely thin splitters for the low frequencies and of the bending vanes suitably jacketed by porous material for the high frequencies. This U-bend silencer was optimized in both its aerodynamic and acoustic performance by extensive model and full-scale laboratory tests. It will enable the wind tunnel to be operated at its design speed with the permanent silencers reducing the fan noise by than 30 dB in a sufficiently broad range of frequencies. For the acoustic lining of the open test section, a new type of acoustic broadband absorber was developed which requires a minimum in space and has again even and smooth surfaces in order to avoid any interference with the flow. Author

A93-19153
ACTIVE AERODYNAMIC CONTROL OF WAKE-AIRFOIL INTERACTION NOISE - EXPERIMENT
J. C. SIMONICH, P. L. LAVRICH, T. G. SOFRIN (United Technologies Research Center, East Hartford, CT), and D. A. TOPOL (Pratt & Whitney Group, East Hartford, CT) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 229-237. refs
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A proof of concept experiment is conducted that shows the potential for active aerodynamic control of rotor wake/stator interaction noise in a simplified manner. A single airfoil model representing the stator was fitted with a moveable trailing edge flap controlled by a servo motor. The control system moves the motor driven flap in the correct angular displacement phase and rate to reduce the unsteady load on the airfoil during the wake interaction. R.E.P.

A93-19154
ACTIVE AERODYNAMIC CONTROL OF WAKE-AIRFOIL INTERACTION NOISE - THEORY
EDWARD J. KERSCHEN (Arizona Univ., Tucson) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 238-249. Research supported by United Technologies Research Center refs

The control of wake-airfoil interaction noise by trailing-edge flap motion is investigated. Time-domain predictions are developed for the unsteady interaction of a single wake with an airfoil. The analysis considers the case of low Mach numbers and O(1) aerodynamic reduced frequencies. The acoustic wavelength is then long compared to the airfoil chord and singular perturbation techniques can be utilized to simplify the problem. Results are presented for the unsteady lift and sound field produced by the wake-airfoil interaction, and for the trailing-edge flap motion required to cancel this sound field. The asymptotic limit of wake widths narrow compared to the airfoil chord is also examined. Two time scales arise in this limit: a short time scale for the wake to pass the airfoil leading edge, and a longer time scale for the resulting unsteady aerodynamic response. Asymptotic formulas are derived for the unsteady lift, sound field, and cancelling flap motion. The narrow wake limit leads to a particulary simple result for the peak of the sound field, which occurs on the short time scale and has the same temporal dependence as the wake upwash which impinges on the leading edge. Author

A93-19155
EXPERIMENTAL INVESTIGATION OF TIP CLEARANCE NOISE IN AXIAL FLOW MACHINES
F. KAMELER, T. NAWROT (Berlin, Technische Univ., Germany), and W. NEISE (DLR, Berlin, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 250-259. refs

An experimental investigation to identify the aeroacoustic generation mechanism of the tip clearance noise of axial turbomachines is presented. Results of an ongoing study into the nature of the tip clearance noise are discussed. Some experimental observations regarding a hysteresis-type behavior of the aerodynamic fan performance and rotating stall inception are described. R.E.P.

A93-19156* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE NOISE FROM SUPERSONIC ELLIPTIC JETS
PHILIP J. MORRIS (Pennsylvania State Univ., University Park) and THONSE R. S. BHAT (NASA, Langley Research Center, Hampton, VA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen,

Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 270-278. refs
(Contract NAG1-1047)

This paper presents calculations of the noise radiated by a supersonic elliptic jet. The large scale structures in the jet, that are the predominant source of noise in the downstream direction, are modeled as instability waves. The evolution of the instability waves is determined by a local, linear, inviscid analysis. An expression is derived for the acoustic field outside the jet and the far field directivity associated with each instability wave. Calculations are performed for a Mach 1.5 elliptic jet with aspect ratio 2:1 and a Mach 2.0 elliptic jet with aspect ratio 2:1 and a Mach 2.0 elliptic jet with aspect ratio 3:1. The mean flow development is taken from experimental results. Comparisons are made with far field acoustic measurements. Author

A93-19159* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

THE EFFECTS OF TEMPERATURE ON SUPERSONIC JET NOISE EMISSION

JOHN M. SEINER, MICHAEL K. PONTON (NASA, Langley Research Center, Hampton, VA), BERNARD J. JANSEN, and NICHOLAS T. LAGEN (*Lockheed Engineering and Sciences Co.*, Hampton, VA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 295-307. refs

This paper examines the generation of sound produced by high temperature supersonic jets. In particular, the question of the importance of supersonic instability waves to noise emission is considered relative to the role of Kelvin-Helmholtz (K-H) instability waves. Here, these waves are taken to be synonymous with the Mach emission process. Jet total temperatures from 313 to 1534 K are investigated using an axisymmetric water cooled supersonic nozzle designed for Mach 2. The aerodynamic and acoustic results of this study indicate that the dominant noise contributors are the K-H waves over the entire temperature range. Good agreement between measured and numerically predicted plume properties are obtained and an elliptic nozzle is used to demonstrate reduction of the K-H waves. Author

A93-19160* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

ACOUSTIC PROPERTIES OF SUPERSONIC HELIUM/AIR JETS AT LOW REYNOLDS NUMBERS

DENNIS K. MCLAUGHLIN, W. D. BARRON, and APPA R. VADDEMPUDI (Pennsylvania State Univ., University Park) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 308-316. refs
(Contract NAG1-1047)
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Experiments have been performed with the objective of developing a greater understanding of the physics of hot supersonic jet noise. Cold helium/air jets are used to easily and inexpensively simulate the low densities of hot air jets. The experiments are conducted at low Reynolds numbers in order to facilitate study of the large-scale turbulent structures (instability waves) that cause most of the radiated noise. Experiments have been performed on Mach 1.5 and 2.1 jets of pure air, pure helium and 10 percent helium by mass. Helium/air jets are shown to radiate more noise than pure air jets due to the increased exit velocity. Microphone spectra are usually dominated by a single spectral component at a predictable frequency. Increasing the jet's helium concentration is shown to increase the dominant frequency. The helium concentration in the test chamber is determined by calculating the speed of sound from the measured phase difference between two microphone signals. Bleeding outside air into the test chamber controls the accumulation of helium so that the hot jet simulation remains valid. The measured variation in the peak radiated noise frequency is in good agreement with the predictions of the hot jet noise theory of Tam et al. Author

A93-19163* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

ASSESSMENT AND DESIGN OF LOW BOOM CONFIGURATIONS FOR SUPERSONIC TRANSPORT AIRCRAFT

CHRISTINE M. DARDEN and KEVIN P. SHEPHERD (NASA, Langley Research Center, Hampton, VA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 334-341. refs

A review is presented of presently utilized sonic boom prediction and minimization techniques. The three-pronged approach - acceptability studies, atmospheric propagation studies, and configuration design and operation, to the sonic boom problem as an element of the High Speed Research Program are discussed. Experimental and theoretical results of concepts designed to validate present minimization methods are given. R.E.P.

A93-19164

ON SOUND ATTENUATION IN BOUNDARY LAYERS

L. M. B. C. CAMPOS (Max-Planck-Inst. fuer Aeronomie, Katlenburg-Lindau, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 342-349. refs

It is shown that significant sound attenuation can occur in a boundary layer when a critical level exists. The acoustic wave equation in an exponential shear flow is solved and it is indicated that there are solutions propagating or evanescent in the free stream. R.E.P.

A93-19167

ON THE ACOUSTIC RADIATION NATURE OF A TURBULENT VORTEX RING

VIKTOR F. KOP'EV (TsAGI, Moscow, Russia) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 361-366. refs

A wide range of fundamental questions associated with dynamic model formulation for 3D aerodynamic sound sources are considered. The possibility of combined experimental and theoretical investigation of aeroacoustic features of a separate vortex ring is presented. The reference theoretical model is examined, an acoustic test is performed and visualization techniques of fast proceeding processes in the vortex ring core are developed. R.E.P.

A93-19172

MATRIX DIFFERENCE EQUATION ANALYSIS OF COUPLED STRUCTURAL-ACOUSTIC MODELS FOR AIRCRAFT FUSELAGE VIBRATION AND INTERIOR NOISE REDUCTION

P. H. DENKE (Douglas Aircraft Co., Long Beach, CA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 396-402. refs

The matrix difference equation method is a computing system for vibration analysis of coupled structural-acoustic finite element models of spatially periodic structures, with applications to aircraft cabin interior noise prediction. The structural and acoustic elements are considered part of a single model, according to the traditional finite element approach, in which nodal displacements are unknowns, and the assembled stiffness and mass matrices are symmetric and banded. The spatially periodic assumption results in large savings in data preparation time and computing cost. The acoustic element is free of artificial constraints, and truly represents a fluid. The element is described in some detail, together with the transformation that eliminates the zero frequency modes resulting from the fluid properties of air. Some recent extensions of the method are presented, and a structural-acoustic model of an aircraft fuselage is described. An appendix clarifies the previously presented mathematical basis of the method. Author

A93-19176* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
BOUNDARY CONDITIONS FOR DIRECT COMPUTATION OF AERODYNAMIC SOUND GENERATION
TIM COLONIUS, SANJIVA K. LELE (Stanford Univ., CA), and PARVIZ MOIN (Stanford Univ., CA; NASA, Ames Research Center, Moffett Field, CA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 438-447. Research supported by U.S. Navy refs

A numerical scheme suitable for the computation of both the near field acoustic sources and the far field sound produced by turbulent free shear flows utilizing the Navier-Stokes equations is presented. To produce stable numerical schemes in the presence of shear, damping terms must be added to the boundary conditions. The numerical technique and boundary conditions are found to give stable results for computations of spatially evolving mixing layers. R.E.P.

A93-19177* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A NEW TECHNIQUE FOR AERODYNAMIC NOISE CALCULATION
J. C. HARDIN (NASA, Langley Research Center, Hampton, VA) and D. S. POPE (Lockheed Engineering and Sciences Co., Hampton, VA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 448-456. refs

A novel method for the numerical analysis of aerodynamic noise generation is presented. The method involves first solving for the time-dependent incompressible flow for the given geometry. This fully nonlinear method that is tailored to extract the relevant acoustic fluctuations seems to be an efficient approach to the numerical analysis of aerodynamic noise generation. R.E.P.

A93-19182
NUMERICAL ANALYSIS OF ACOUSTIC EFFECT OF ROTOR WAKES IN ROTOR-STATOR INTERACTION
WEI TANG (U.S. Navy, David Taylor Research Center, Annapolis, MD) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 496-501. Research supported by U.S. Navy refs

A critical noise source in turbomachinery due to rotor-stator interaction is studied by the numerical solutions of Navier-Stokes equations. The two-dimensional unsteady flow equations are solved using an implicit upwind finite difference algorithm. A patched grid technique is applied in the multi-grid system. Non-reflecting boundary conditions are applied at inflow and outflow boundaries. It is found that the wake generated from the trailing edge of the upstream rotor has significant influence on the downstream stator row and the blade surface. The impingement of the rotor wake on the stator leading edge causes noticeable variations on the stator surface pressure distribution. Results of unsteady fluctuations of the flow field variables are presented in both rotating and stationary frames over several rotor passages. Author

A93-19183
TRANSMISSION OF SOUND THROUGH A ROTOR
J. B. H. M. SCHULTEN (National Aerospace Lab., Amsterdam, Netherlands) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 502-509. Research sponsored by Netherlands Agency for Aerospace Programs refs

The dominant sound of a turbofan engine is usually generated by rotor wakes when they impinge on a downstream stator. Consequently, to reach the intake the sound waves must pass the rotor. The rotating blades represent an obstacle that partly reflects and partly transmits the incident sound field. The present paper discusses the calculation of this process by means of a 3D lifting surface approximation of the rotor. It is shown that the reflection-transmission process can be treated as an unsteady aerodynamic problem. The method used will be illustrated by means of numerical examples. It appears that, depending on the relative angle of incidence of the sound waves, the shielding effect of the rotor can yield a reduction from negligible up to the order of 30 dB in acoustic power. Author

A93-19184 National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ADVANCES IN TILT ROTOR NOISE PREDICTION
A. R. GEORGE, C. D. COFFEN, and T. D. RINGLER (Cornell Univ., Ithaca, NY) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 510-531. Research supported by NASA-Cornell Univ. Space Grant Program refs
(Contract NAG2-554; NAS1-19145; NAS1-19000)

The two most serious tilt rotor external noise problems, hover noise and blade-vortex interaction noise, are studied. The results of flow visualization and inflow velocity measurements document a complex, recirculating highly unsteady and turbulent flow due to the rotor-wing-body interactions characteristic of tilt rotors. The wing under the rotor is found to obstruct the inflow, causing a deficit in the inflow velocities over the inboard region of the rotor. Discrete frequency harmonic thickness and loading noise mechanisms in hover are examined by first modeling tilt rotor hover aerodynamics and then applying various noise prediction methods using the WOPWOP code. The analysis indicates that the partial ground plane created by the wing below the rotor results in a primary sound source for hover. C.A.B.

A93-19186* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EVALUATION OF PIEZOCERAMIC ACTUATORS FOR CONTROL OF AIRCRAFT INTERIOR NOISE
RICHARD J. SILCOX (NASA, Langley Research Center, Hampton, VA), SYLVIE LEFEBVRE (Virginia Polytechnic Inst. and State Univ., Blacksburg), VERN L. METCALF (U.S. Army, Aviation Systems Command, Hampton, VA), TODD B. BEYER (NASA, Langley Research Center, Hampton, VA), and CHRIS R. FULLER (Virginia Polytechnic Inst. and State Univ., Blacksburg) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 542-551. refs

Results of an experiment to evaluate piezoceramic actuators as the control actuator for active control of interior noise in a large-scale fuselage model are presented. Control was demonstrated for tonal excitation using a time domain least mean squares algorithm. A maximum of four actuator channels and six error signals were used. The actuators were employed for control of noise at frequencies where interior cavity modes were the dominant response and for driven acoustic responses where a structure resonance was dominant. Global reductions of 9 to 12 dB were obtained for the cases examined. The most effective configuration of skin-mounted actuators was found to be a pure in-plane forcing function as opposed to a bending excitation. The frame-mounted actuators were found to be equally effective as the skin-mounted actuators. However, both configurations resulted in local regions of unacceptably high vibration response in the structure. C.A.B.

A93-19187
ACTIVE CONTROL OF SOUND TRANSMISSION THROUGH STIFF LIGHTWEIGHT COMPOSITE FUSELAGE CONSTRUCTIONS
D. R. THOMAS, P. A. NELSON, R. J. PINNINGTON, and S. J. ELLIOTT (Southampton Univ., United Kingdom) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 552-560. refs

A possible means of controlling the transmission of noise into the cabin of a propeller driven aircraft is to replace part of the internal trim with stiff, light composite panels and the use of

vibration actuators acting as secondary force inputs between these panels and the fuselage. A simple analytical model of such a panel freely mounted in a rigid baffle between two half spaces is outlined and the results of computer simulations are presented where point secondary force inputs to the panel are used to minimize the sound transmitted. It is assumed that there is a single frequency plane wave incident on one side of the panel. Experiments carried out using a freely mounted aluminum honeycomb composite panel mounted between two reverberation chambers are outlined. A single frequency primary source is placed in the source chamber and the Multiple Error LMS algorithm is used to minimize the sum of the squared pressures at 24 microphones in the receiving chamber by adjusting the outputs of three force actuators attached to the honeycomb panel. The results for frequencies between 80 Hz and 100 Hz are presented and discussed. Further experiments are also described where a clamped steel plate also in place and secondary force acting between the two panels. Results for the same frequency range are presented and briefly discussed. Author

A93-19190
A CONTRIBUTION TO NOISE IMPROVEMENTS FOR AIRCRAFT BY NOISE MEASUREMENT EVALUATION
FRANK WEIBLEN (MT - Propeller Entwicklung GmbH & Co., Atting, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 623-627. refs

Constraints for the design of modern low-noise propellers are discussed on the basis of noise measurement evaluation of various propeller-driven aircraft according to ICAO Annel 16 standards, Chapter VI (flyover noise) and Chapter X (take-off noise). Reduction of propeller speed and propeller diameter are the most valuable parameters to be changed. Both are used in changing propeller installations on existing aircraft in order to satisfy the latest noise allowables. This is attainable with advanced variable pitch propellers using round blade-tips and high lift profiles in the outer blade portions. The effects of propeller-speed reduction, diameter reduction, transition fixed pitch to variable pitch propeller, and lower manifold pressure are discussed. C.A.B.

A93-19195* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ON THE SCALING OF SMALL-SCALE JET NOISE TO LARGE SCALE
PAUL T. SODERMAN and CHRISTOPHER S. ALLEN (NASA, Ames Research Center, Moffett Field, CA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 663-671. refs

An examination was made of several published jet noise studies for the purpose of evaluating scale effects important to the simulation of jet aeroacoustics. Several studies confirmed that small conical jets, one as small as 59 mm diameter, could be used to correctly simulate the overall or PNL noise of large jets dominated by mixing noise. However, the detailed acoustic spectra of large jets are more difficult to simulate because of the lack of broad-band turbulence spectra in small jets. One study indicated that a jet Reynolds number of 5 x 10 exp 6 based on exhaust diameter enabled the generation of broad-band noise representative of large jet mixing noise. Jet suppressor aeroacoustics is even more difficult to simulate at small scale because of the small mixer nozzles with flows sensitive to Reynolds number. Likewise, one study showed incorrect ejector mixing and entrainment using small-scale, short ejector that led to poor acoustic scaling. Conversely, fairly good results were found with a longer ejector and, in a different study, with a 32-chute suppressor nozzle. Finally, it was found that small-scale aeroacoustic resonance produced by jets impacting ground boards does not reproduce at large scale. Author

A93-19196
CONTROL OF COHERENT STRUCTURES AND AERO-ACOUSTIC CHARACTERISTICS OF SUBSONIC AND SUPERSONIC TURBULENT JETS
E. V. VLASOV, A. S. GINEVSKII, and V. G. PIMSHTEIN (TsAGI, Moscow, Russia) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 672-678. refs

Three important problems associated with the role of large-scale coherent structures of jet flows in turbulent mixing processes and in aerodynamic noise generation are investigated in the present work. Firstly, new data illustrating the relation between coherent subsonic jet structures and their sensitivity to the periodic excitation and the jet noise in its far and near field are received. Secondly, from visual investigations of subsonic turbulent jets under high-intensity sound wave excitation there was investigated the interaction of sound waves and large-scale vortex structures generated by them. Thirdly, noise reduction methods for subsonic and supersonic non-isobaric turbulent jets are studied. Those methods are based on the aeroacoustic interaction effect. Author

A93-19201
A NUMERICAL METHOD FOR THE PREDICTION OF QUADRUPOLE SHOCK WAVE NOISE
PAOLO DI FRANCESCANTONIO (Agusta S.p.A., Milan, Italy) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 714-723. Research supported by EEC refs

The study presents a numerical method for the prediction of the surface component of the quadrupole term of the FWH equation. The problem of the integration on a deformable surface is solved using a finite-element-like schematization that automatically makes it possible to execute a local mapping of the deformable panels into indeformable elements on which the integration is performed. This approach presents advantages with respect to a global mapping of the surface, since there is no longer a need for an external code to perform the mapping and since the shock wave no longer has to remain topologically equivalent during the motion. Even if it is specialized for the prediction of the shock wave noise, this method is a general approach that allows the evaluation of all the surface terms of the FWH equation with a unique formulation. P.D.

A93-19202* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HELICOPTER NOISE PREDICTION - THE CURRENT STATUS AND FUTURE DIRECTION
KENNETH S. BRENTNER and F. FARASSAT (NASA, Langley Research Center, Hampton, VA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 724-735. refs

The paper takes stock of the progress, assesses the current prediction capabilities, and forecasts the direction of future helicopter noise prediction research. The acoustic analogy approach, specifically, theories based on the Ffowcs Williams-Hawkings equations, are the most widely used for deterministic noise sources. Thickness and loading noise can be routinely predicted given good plane motion and blade loading inputs. Blade-vortex interaction noise can also be predicted well with measured input data, but prediction of airloads with the high spatial and temporal resolution required for BVI is still difficult. Current semiempirical broadband noise predictions are useful and reasonably accurate. New prediction methods based on a Kirchhoff formula and direct computation appear to be very promising, but are currently very demanding computationally. P.D.

A93-19203
EFFECT OF NOZZLE DESIGN ON NEAR ACOUSTIC FIELD OF SUPERSONIC CIRCULAR AND RECTANGULAR JETS

E. GUTMARK, H. L. BOWMAN, and K. C. SCHADOW (U.S. Navy, Naval Air Warfare Center, China Lake, CA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 736-745. refs

Measurements of the flowfield and near field pressure fluctuations of circular and rectangular jets at a wide range of pressure ratios corresponding to exit Mach number of 1 to 2.5 (after external isentropic expansions) are reported. Three rectangular jets, differing by the internal design of the divergence section, were tested. The changes in the internal design had substantial effects on the jet behavior. Typically, the jets exhibited asymmetric flapping mode at their minor axis plane, when operated at off-design conditions. This mode resulted in an enhanced spreading rate. Axis switching was observed in one of the rectangular jets, but the other two showed enhanced growth rate at both axes. The flapping mode instability also resulted in an increased screech level. The asymmetric components of the fluctuations dominated the region upstream of the nozzle exit, while the other modes covered the downstream region. The pressure fluctuations level at the jet edge and the radial decay rate were found to be different at the major and minor axis planes of the different jets and also to vary with the pressure ratio. P.D.

A93-19206

EXPERIMENTAL INVESTIGATIONS AND EFFICIENCY PREDICTION OF JET NOISE REDUCTION TECHNIQUES

VLADIMIR M. KUZNETSOV (TsAGI, Moscow, Russia) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 761-766. refs

The study presents prediction evaluation results and compares them with an experimental investigation of the efficiency of a number of jet noise reduction techniques. The space noise distrbution of turbulent jet parts of different lengths is predicted. The sound field evaluation is based on an analysis of convective wave equation solutions and on the application of experimental data on turbulence characteristics in the mixing region. The sound field prediction results for turbulent jet parts are used to evaluate jet flow noise by dividing the mixing regions into separate parts and by estimating the acoustic radiation intensity of those parts. The jet noise reduction efficiency is evaluated by by-pass nozzles due to the 'inverted' velocity profile application as well as the efficiency of multijet devices used at the nozzle exit plane. P.D.

A93-19209

THE ACOUSTIC RESPONSE OF ALTITUDE TEST FACILITY EXHAUST SYSTEMS TO AXISYMMETRIC AND TWO-DIMENSIONAL TURBINE ENGINE EXHAUST PLUMES

R. R. JONES, III and G. R. LAZALIER (Sverdrup Technology, Inc., Arnold AFB, TN) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 785-794. refs

During testing of advanced technology engines equipped with both convergent axisymmetric and 2D convergent-divergent vectoring nozzles, plume/facility coupling has been experienced. These interactions, whose onset was associated with specific and repeatable nozzle operation conditions, produced unacceptably high noise levels (165-170 dB) within the facility exhaust system. Diagnostic testing in the full-scale environment was used to characterize the excited facility resonant modes and to investigate the sensitivity of the interaction to selected nozzle and facility configuration changes aimed at suppressing the interaction. A computational study of the full-scale nozzle internal flow was undertaken to identify fluid dynamic phenomena which may contribute to the interaction. Results from these diagnostic efforts are described along with preliminary results from a follow-on subscale test program. The objective of the subscale effort is replication of the full-scale event, thereby providing a mechanism for detailed study of the interaction physics. P.D.

A93-19212

ACOUSTIC PERFORMANCE OF LOW PRESSURE AXIAL FAN ROTORS WITH DIFFERENT BLADE CHORD LENGTH AND RADIAL LOAD DISTRIBUTION

THOMAS CAROLUS (Siegen, Univ.-Gesamthochschule, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 809-815. refs

The paper examines the acoustic and aerodynamic performance of low-pressure axial fan rotors with a hub/tip ratio of 0.45. Six rotors were designed for the same working point by means of the well-known airfoil theory. The condition of an equilibrium between the static pressure gradient and the centrifugal forces is maintained. All rotors have unequally spaced blades to diminish tonal noise. The rotors are tested in a short cylindrical housing without guide vanes. All rotors show very similar flux-pressure difference characteristics. The peak efficiency and the noise performance is considerably influenced by the chosen blade design. The aerodynamically and acoustically optimal rotor is the one with the reduced load at the hub and increased load in the tip region under satisfied equilibrium conditions. It runs at the highest aerodynamic efficiency, and its noise spectrum is fairly smooth. The overall sound pressure level of this rotor is up to 8 dB (A) lower compared to the other rotors under consideration. P.D.

A93-19213

AEROACOUSTIC WIND TUNNEL TESTING OF A COUNTERROTATING SHROUDED PROPFAN-MODEL

W. DOBRZYNSKI, B. GEHLHAR, and J. BOETTCHER (DLR, Inst. fuer Entwurfsaerodynamik, Braunschweig, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 816-825. refs

Results of acoustic wind tunnel testing of a counterrotating integrated shrouded propfan model-scale engine are presented. The test matrix entailed variations of relevant operational parameters, such as rotational speed, fan-blade stagger angle, wind tunnel speed, and inflow angle. The azimuthal noise level patterns were observed to be either dominated by rotor 1/rotor 2 or rotor 2/strut interaction noise. Rotor/rotor-interaction noise is radiated into the rear arc with maximum levels at the third rotational harmonic. This harmonic level largely determines the maximum overall A-weighted noise level at high rotational speeds. At low rotational speeds, broadband noise contributes significantly to the total noise signature with a pronounced level maximum in the rear arc. P.D.

A93-19214

EXPERIMENTAL DETERMINATION OF THE MAIN NOISE SOURCES IN A PROFAN MODEL BY ANALYSIS OF THE ACOUSTIC SPINNING MODES IN THE EXIT PLANE

F. HOLSTE and W. NEISE (DLR, Berlin, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 826-835. refs

An experimental investigation is described to explore the dominant sound generation mechanisms of the tonal noise components of the MTU-CRISP propfan model. For this purpose, the sound field in the exit plane is measured using 1/4 inch microphones with nose cone. Initial tests proved than the presence of the microphone probes in the exit flow does not interfere with the sound pressure distribution. Experimental results of the mode distributions show that the blade passing frequency component is generated mainly by the interaction mechanisms between the rotors and the struts and/or by a transformation of acoustics modes at the struts. For all higher harmonics, the interaction between the two counter rotating rotors is the main noise source. The relative importance of the various interaction mechanisms is discussed for various shroud geometries, blade profiles, blade stagger angles, thrust conditions, angles of incidence, and wind tunnel speeds. Author

A93-19215* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
RADIATED NOISE OF DUCTED FANS
WALTER EVERSMAN (Missouri-Rolla, Univ., Rolla) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche *Gesellschaft fuer Luft- und Raumfahrt* 1992 p. 836-845. Research supported by NASA refs

The differences in the radiated acoustic fields of ducted and unducted propellers of the same thrust operating under similar conditions are investigated. An FEM model is created for the generation, propagation, and radiation of steady, rotor alone noise and exit guide vane interaction noise of a ducted fan. For a specified number of blades, angular mode harmonic, and rotor angular velocity, the acoustic field is described in a cylindrical coordinate system reduced to only the axial and radial directions. It is found that, contrary to the usual understanding of the Tyler and Sofrin (1962) result, supersonic tip speed rotor noise can be cut off if the tip Mach number is only slightly in excess of unity and if the number of blades is relatively small. If there are many blades, the fundamental angular mode number is large, and the Tyler and Sofrin result for thin annuli becomes more relevant. Shrouding of subsonic tip speed propellers is a very effective means of controlling rotor alone noise. P.D.

A93-19216
PREDICTION OF JET MIXING NOISE IN HIGH-SPEED FLIGHT
ULF MICHEL (DLR, Inst. fuer Experimentelle Stroemungsmechanik, Berlin, Germany) and JAN BOETTCHER (DLR, Inst. fuer Entwurfsaerodynamik, Braunschweig, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 846-853. Previously announced in STAR as N93-10685 refs

A method for the prediction of single stream jet mixing noise in flight is presented that can be used for flight Mach numbers up to 0.9. The method is similar to the empirical SAE method. However, two important results of the theoretical scaling law of Michalke and Michel are incorporated: (1) the total noise of heated jets is separated into quadrupole and dipole noise components because they are influenced differently by the flight Mach number and, (2) the influence of the stretching of the jet plume in flight on the overall sound pressure and the frequency of the emitted sound is considered. A relative velocity exponent law is used to correlate experimental flyover data. The correlation is based on all available data for combat aircraft with fuselage mounted engines and flight Mach numbers between 0.5 and 0.9. The difference between predictions with this new method and measured overall flyover levels is generally less than two decibels. The spectra are also well predicted. Author

A93-19218
THE NOISE OF JET AIRCRAFT FLYING WITH HIGH SPEEDS AT LOW ALTITUDES
JAN BOETTCHER (DLR, Inst. fuer Entwurfsaerodynamik, Braunschweig, Germany) and ULF MICHEL (DLR, Inst. fuer Experimentelle Stroemungsmechanik, Berlin, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche *Gesellschaft fuer Luft- und Raumfahrt* 1992 p. 863-872. Research supported by BMVg refs

Flyover noise measurements are evaluated for four different military jet aircraft types flying at low altitudes. Flight Mach numbers ranged from 0.5 to 0.9. The analysis shows that noise emission is likely caused by jet mixing and broadband shock associated noise. Results from novel prediction schemes for both noise sources are compared with the experimental data. It is demonstrated that the schemes describe the observed acoustic signatures quite accurately. This holds for the overall sound pressure level in dependence of the emission angle and for one-third-octave spectra. The prediction schemes are used to demonstrate and quantify the noise reduction potential achievable by varying flight Mach number and flight altitude. Author

A93-19223
EXPERIMENTAL RESULTS ON PROPELLER NOISE ATTENUATION USING AN 'ACTIVE NOISE CONTROL' TECHNIQUE
M. KALLERGIS (DLR, Inst. fuer Entwurfsaerodynamik, Braunschweig, Germany) *In* DGLR/AIAA Aeroacoustics *Conference, 14th, Aachen, Germany, May 11-14, 1992,* Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 907-918. refs

The 'active noise' control technique is employed to demonstrate the feasibility of attenuating the noise of propeller aeroplanes equipped with a piston engine. In ground-stationary tests it is shown that for a typical GA-type single engine propeller-driven aeroplane, differences in the overall sound pressure levels of up to 5 dB were obtained between a 'random' and an exact antiphase superposition of the sound waves from the propeller and the engine exhaust. The sound pressure levels of the first nine harmonics of the blade passage frequency were found to be reduced. Additional fly-over experiments yielded differences on the ground ranging from 4 to 6 dB between optimum and 'random' relative positions of the crankshaft and the propeller. P.D.

A93-19224
REDUCTION OF PROPELLER NOISE BY ACTIVE NOISE CONTROL
O. BSCHORR (MBB GmbH, Munich, Germany) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 919-928. refs

The possibilities of the antinoise technique for reducing propeller noise are explored using a mathematical model to simulate the propeller noise and the antinoise. With this model the noise footprints of a propeller engine with and without antinoise is calculated for the two main components, the blade-thickness noise, and the thrust noise. Using a single antinoise source, it is possible to reduce the peak level more than 10 dB, but away from the optimum cancellation direction and for the higher harmonics the superposition causes an amplification. This effect can be avoided by changing the cancellation direction and also by reducing the acoustic power of the antinoise source. With an antinoise power of only 25 percent of the propeller noise, a noise reduction of about 5 dB is obtained within a cone of 45 deg. When two or more antinoise sources are used, the cancellation region can be enlarged, up to an omnidirectional noise reduction. P.D.

A93-19226
WING VORTEX REFRACTION EFFECTS FROM BAC 1-11 FLIGHT TESTS
W. D. BRYCE (Royal Aircraft Establishment, Farnborough, United Kingdom) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, *Proceedings. Vol. 2* Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 936-939. refs
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A series of noise measurements made in 1976 using a BAC 1-11 aircraft are analyzed in order to elucidate the sideline noise characteristics of aircraft with rear-fuselage engine installations. In these tests, aimed at measuring the effects of wing vortices on the engine noise radiation, the aircraft was flown in a large flat circular arc at 0.25 M and at a bank angle of 20 deg, crossing a radial microphone array at a height of 500 ft. The frequency range of the acceptable data falls into three octaves with center frequencies of 500 Hz, 1 kHz, and 2 kHz, and the variation of the aircraft octave sound pressure levels as a function of the azimuth angle are presented. There are marked dips in the noise levels, peaking at 6.5 dB, at angles near the wing plane, and there is little dependence on frequency over the range studied. Noise reductions are evident to about 20 deg below the wing plane. It is suggested that the observed radiation patterns arise primarily from wing vortex refraction effects, although jet-by-jet shielding effects are a contributor. P.D.

A93-19229* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

EXPERIMENTAL AND ANALYTICAL INVESTIGATIONS OF FUSELAGE MODAL CHARACTERISTICS AND STRUCTURAL-ACOUSTIC COUPLING

MYLES A. SIMPSON and GOPAL P. MATHUR (Douglas Aircraft Co., Long Beach, CA) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 958-963. refs

(Contract NAS1-18037)

Measurements conducted on a DC-9 aircraft test section to define the shell and cavity modes of the fuselage, understand its structural-acoustic coupling characteristics, and measure its response to different types of acoustic and vibration excitations are reported. The data were processed to generate spatial plots and wavenumber maps of the shell acceleration and cabin acoustic pressure field. Analysis and interpretation of the spatial plots and wavenumber maps showed that the only structural-acoustic coupling occurred at 105 Hz between the N=2 circumferential structural mode and the (n=2, p=0) circumferential cavity mode. The fuselage response to vibration excitation was found to be dominated by modes whose order increases with frequency. P.D.

A93-19230

VIBRO-ACOUSTIC ANALYSIS OF PROPELLER AIRCRAFT, INTEGRATING ADVANCED EXPERIMENTAL MODELING WITH IN-FLIGHT DATA ANALYSIS

DIRK OTTE, HERMAN VAN DER AUWERAER (LMS International, Louvain, Belgium), MATS GUSTAVSSON, and URBAN EMBORG (SAAB Scania, AB, Aircraft Div., Linkoeping, Sweden) *In* DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 2 Bonn Deutsche Gesellschaft fuer Luft- und Raumfahrt 1992 p. 964-970. refs

Some global experimental modeling techniques for complex vibro-acoustic systems based on singular value decomposition of a measured frequency response function matrix are discussed. Two related modeling concepts, principal field shape analysis and the U-vector expansion method, are introduced and illustrated by test examples on a fully trimmed twin-engine aircraft. Some flight data analysis techniques based on coherence methods are also described. P.D.

A93-19804*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

ACCURACY CONSIDERATIONS IN THE COMPUTATIONAL ANALYSIS OF JET NOISE

JAMES N. SCOTT (Ohio State Univ., Columbus) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs

(Contract NAG3-1058)

(AIAA PAPER 93-0146) Copyright

The application of computational fluid dynamics methods to the analysis of problems in aerodynamic noise has resulted in the extension and adaptation of conventional CFD to the discipline now referred to as computational aeroacoustics (CAA). In the analysis of jet noise accurate resolution of a wide range of spatial and temporal scales in the flow field is essential if the acoustic far field is to be predicted. The numerical simulation of unsteady jet flow has been successfully demonstrated and many flow features have been computed with reasonable accuracy. Grid refinement and increased solution time are discussed as means of improving accuracy of Navier-Stokes solutions of unsteady jet flow. In addition various properties of different numerical procedures which influence accuracy are examined with particular emphasis on dispersion and dissipation characteristics. These properties are investigated by using selected schemes to solve model problems for the propagation of a shock wave and a sinusoidal disturbance. The results are compared for the different schemes. Author

A93-20316

HIGH SPEED FLIGHT EFFECTS ON TRANSMISSION OF SOUND THROUGH A NONFLEXIBLE VIBRATING PANEL DUE TO FLOW STRUCTURAL INTERACTION IN THE AMBIENCE

R. DASH (Acoustics Research and Noise Control, Arlington, VA) *In* AIAA/USAF/NASA/OAI Symposium on Multidisciplinary Analysis and Optimization, 4th, Cleveland, OH, Sept. 21-23, 1992, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1992 p. 168-179.

(AIAA PAPER 92-4708) Copyright

In combining the disciplines of flow acoustics with the structural dynamics into a rational prediction model, this paper predicts the effects of high speed flight, Mf = 0.8-1.2, on the interior and exterior acoustics of an UHBR aircraft. As a result of this cruising speed, giving rise to an abnormally high impingement of the perturbed flow field, there is a very high level of acoustics buildup which takes place both within and outside of the frontal panel of the aircraft. Quantitatively, they are expressed in terms of the reflection and the transmission coefficients of sound which are now expressed in terms of the structural properties (stiffness, damping, and the surface density) of the panel, acoustic impedances of the media, and also the Mach number of the flight. Results of this research tell us very pointedly that in order for the UHBR-aircraft to be commercially viable in the market place, suppression of the interior acoustics at this high cruising speed must first be considered while dealing with the high speed technology surrounding this proposed aircraft of the future. Author

A93-21727

EXPERIMENTAL STUDY ON THE CHARACTERISTICS OF THE NEAR WAKE OF A ROTATING FLAT PLATE. III - INFLUENCE OF THE SHAPE NEAR THE TRAILING EDGE ON PERIODIC-VELOCITY-FLUCTUATION PHENOMENA

TOHRU FUKANO, MINORU FUKUHARA, HIROSHI ISOBE, YASUO HIRONAKA, and HIDECHITO HAYASHI Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 58, no. 551 July 1992 p. 2087-2092. In Japanese. refs

Copyright

We have experimentally investigated the influence of the shape near the trailing edge of a flat-plate blade on the periodic velocity fluctuation in the near wake of the single rotating blade. The results show that the characteristics of the near wake in the rotating flow field are similar to those in the uniform flow field; i.e., the periodic velocity fluctuation did not occur when the suction surface of the blade was scraped near the trailing edge, and did occur if the pressure surface was scraped. In the latter case, the two types of trailing edge separations occur. The flow always separates at the trailing edge of the blade on the suction side, while the flow separation alternately originates from two different points, i.e., from either the starting point of the scraping or from a fixed point on the scraped surface. Author

A93-21859

RADIATION MECHANISM FOR THE AERODYNAMIC SOUND OF GEARS - AN EXPLANATION FOR THE RADIATION PROCESS BY AIR FLOW OBSERVATION

HARUO HOUJOH (Tokyo Inst. of Technology, Yokohama, Japan) JSME International Journal, Series III (ISSN 0914-8825) vol. 35, no. 4 Dec. 1992 p. 623-632. refs

Copyright

One specific feature of the aerodynamic sound produced at the face end region is that the radiation becomes equally weak by filling root spaces as by shortening the center distance. However, one can easily expect that such actions make the air flow faster, and consequently make the sound louder. This paper attempts to reveal the reason for such a feature. First, air flow induced by the pumping action of the gear pair was analyzed regarding a series of root spaces as volume varying cavities which have channels to adjacent cavities as well as the exit/inlet at the face ends. The numerical analysis was verified by the hot wire anemometer measurement. Next, from the obtained flow response, the sound source was estimated to be a combination of symmetrically

distributed simple sources. Taking the effect of either the center distance or root filling into consideration, it is shown that the simplified model can explain such a feature rationally. Author

A93-22357#
CHARACTERIZATION OF ELECTRON BEAM PROPAGATION FOR HYPERSONIC FLIGHT RESEARCH APPLICATIONS
ROBERT J. CATTOLICA (California Univ., La Jolla), LEONARD H. CLAPP, and ROBERT G. TWISS (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) Dec. 1992 12 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 Research supported by National Aerospace Plane Joint Program Office refs
(AIAA PAPER 92-5087) Copyright

Research conducted under the NASP program is summarized which is aimed at improving the technology base needed to apply electron-beam diagnostics in hypersonic studies in both wind tunnel and flight experiments. Two-dimensional measurements of the N2 (+)(0,0)-band fluorescence were used to obtain beam divergence characteristics of electron beams (10 and 20 keV) propagating through either nitrogen or air at selected pressures (0.05, 0.1, 0.2, 0.4, and 0.8 torr). It was found that the fluorescence signal integrated across the beam is proportional to the gas density for at least 75 mm along the beam propagation direction. Two beam propagation models, a heuristic model based on an assumed self-similar expansion and a single scattering model, are evaluated. For hypersonic flight research applications in the altitude range of 150-200 kft, a 50 keV, 10 mA electron beam is recommended for hypersonic boundary layer measurement up to a gas target thickness of 6 torr-cm. O.G.

A93-22589#
NUMERICAL PREDICTION OF AERODYNAMIC NOISE RADIATED FROM LOW MACH NUMBER TURBULENT WAKE
CHISACHI KATO, AKIYOSHI IIDA, YASUSHI TAKANO, HAJIME FUJITA, and MASAHIRO IKEGAWA (Hitachi, Ltd., Mechanical Engineering Research Lab., Japan) Jan. 1993 9 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0145) Copyright

Aerodynamic noise radiated from low Mach number turbulent wake of a circular cylinder has been numerically predicted by the following two-step approach. First, the three-dimensional unsteady incompressible Navier-Stokes equations are solved by the large eddy-simulation (LES) technique using a newly proposed streamline upwind finite element method. The far field sound pressure is then calculated from the fluctuating surface pressure on the cylinder, based on the Lighthill-Curle's equation. A sophisticated method has been proposed for computing sound pressure level (SPL) radiated from the whole span of the cylinder using the surface pressure fluctuation obtained in a small spanwise computational domain. The method takes the effects of the random phase shift of the surface pressure fluctuation into account. The predicted SPL is compared with the measured value. A fairly good agreement has been achieved between the predicted and measured SPL's for the peak spectrum intensity and the frequency dependency of the SPL up to about ten times higher than the peak frequency. Author

A93-23241# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PROPAGATION OF HIGH FREQUENCY JET NOISE USING GEOMETRIC ACOUSTICS
A. KHAVARAN (Sverdrup Technology, Inc., Brook Park, OH) and E. A. KREJSA (NASA, Lewis Research Center, Cleveland, OH) Jan. 1993 17 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Previously announced in STAR as N93-15575 refs
(Contract RTOP 537-02-23)
(AIAA PAPER 93-0147) Copyright

Spherical directivity of noise radiated from a convecting quadrupole source embedded in an arbitrary spreading jet is obtained by ray-tracing methods of geometrical acoustics. The six propagation equations are solved in their general form in a rectangular coordinate system. The noise directivity in the far field is calculated by applying an iteration scheme that finds the required radiation angles at the source resulting in propagation through a given observer point. Factors influencing the zone of silence are investigated. The caustics of geometrical acoustics and the exact locations where it forms is demonstrated by studying the variation in ray tube area obtained from transport equation. For a ring source convecting along the center-axis of an axisymmetric jet, the polar directivity of the radiated noise is obtained by an integration with respect to azimuthal directivity of compact quadrupole sources distributed on the ring. The Doppler factor is shown to vary slightly from point to point on the ring. Finally the scaling of the directivity pattern with power -3 of Doppler factor is investigated and compared with experimental data. Author

A93-23323*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ACTIVE CONTROL OF FAN NOISE FROM A TURBOFAN ENGINE
RUSSELL H. THOMAS, RICARDO A. BURDISSO, CHRISTOPHER R. FULLER, and WALTER F. O'BRIEN (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jan. 1993 10 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by NASA refs
(AIAA PAPER 93-0597) Copyright

A three channel active control system is applied to an operational turbofan engine in order to reduce tonal noise produced by both the fan and high pressure compressor. The control approach is the feedforward filtered-x least-mean-square algorithm implemented on a digital signal processing board. Reference transducers mounted on the engine case provides blade passing and harmonics frequency information to the controller. Error information is provided by large area microphones placed in the acoustic far field. In order to minimize the error signal, the controller actuates loudspeakers mounted on the inlet to produce destructive interference. The sound pressure level of the fundamental tone of the fan was reduced using the three channel controller by up to 16 dB over a 60 deg angle about the engine axis. A single channel controller could produce reduction over a 30 deg angle. The experimental results show the control to be robust. Simultaneous control of two tones is done with parallel controllers. The fundamental and the first harmonic tones of the fan were controlled simultaneously with reductions of 12 dBA and 5 dBA, respectively, measured on the engine axis. Simultaneous control was also demonstrated for the fan fundamental and the high pressure compressor fundamental tones. Author

A93-23744 National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
APPROXIMATION METHODS FOR CONTROL OF STRUCTURAL ACOUSTICS MODELS WITH PIEZOCERAMIC ACTUATORS
H. T. BANKS, W. FANG (Southern California Univ., Los Angeles, CA), R. J. SILCOX (NASA, Langley Research Center, Hampton, VA), and R. C. SMITH (ICASE; NASA, Langley Research Center, Hampton, VA) Journal of Intelligent Material Systems and Structures (ISSN 1045-389X) vol. 4, no. 1 Jan. 1993 p. 98-116. Previously announced in STAR as N92-15658 refs
(Contract AF-AFOSR-90-0091; NAG1-1116; NAS1-18107; RTOP 505-90-52-01)
Copyright

The active control of acoustic pressure in a 2-D cavity with a flexible boundary (a beam) is considered. Specifically, this control is implemented via piezoceramic patches on the beam which produces pure bending moments. The incorporation of the feedback control in this manner leads to a system with an unbounded input term. Approximation methods in this manner leads to a system with an unbounded input term. Approximation methods in this manner leads to a system with an unbounded input team. Approximation methods in the context of linear quadratic regulator (LQR) state space control formulation are discussed and numerical

results demonstrating the effectiveness of this approach in computing feedback controls for noise reduction are presented.
Author

N93-15980# Naval Postgraduate School, Monterey, CA.
OPTIMIZATION OF AN INTERNALLY FINNED ROTATING HEAT PIPE M.S. Thesis
GERALDINE L. OLSON Jun. 1992 72 p
(AD-A256725) Avail: CASI HC A04/MF A01

A finite element formulation with linear triangular elements was used to solve the steady-state, two-dimensional conduction heat transfer equation in the condenser wall section of an internally finned rotating heat pipe. A FORTRAN program using this method was coupled with the ADS program for automated design of the internal heat pipe fin geometry to optimize heat transfer. An increase in surface area, which increases heat transfer, also increases the condensate level, which decreases heat transfer. The additional condensate level does not offset the advantage gained by the increased surface area. The investigation provided combinations of fin half angle, number of fins, and fin height for an optimum design. Water is used as the working fluid and the heat pipe is constructed from copper. GRA

N93-16755*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECT OF SONIC BOOM ASYMMETRY ON SUBJECTIVE LOUDNESS
JACK D. LEATHERWOOD and BRENDA M. SULLIVAN (Lockheed Engineering and Sciences Co., Hampton, VA.) Dec. 1992 32 p
(Contract RTOP 537-03-21-03)
(NASA-TM-107708; NAS 1.15:107708) Avail: CASI HC A03/MF A01

The NASA Langley Research Center's sonic boom apparatus was used in an experimental study to quantify subjective loudness response to a wide range of asymmetrical N-wave sonic boom signatures. Results were used to assess the relative performance of several metrics as loudness estimators for asymmetrical signatures and to quantify in detail the effects on subjective loudness of varying both the degree and direction of signature loudness asymmetry. Findings of the study indicated that Perceived Level (Steven's Mark 7) and A-weighted sound exposure level were the best metrics for quantifying asymmetrical boom loudness. Asymmetrical signatures were generally rated as being less loud than symmetrical signatures of equivalent Perceived Level. The magnitude of the loudness reductions increased as the degree of boom asymmetry increased, and depended upon the direction of asymmetry. These loudness reductions were not accounted for by any of the metrics. Corrections were determined for use in adjusting calculated Perceived Level values to account for these reductions. It was also demonstrated that the subjects generally incorporated the loudness components of the complete signatures when making their subjective judgments. Author

N93-17051*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CONSECUTIVE PLATE ACOUSTIC SUPPRESSOR APPARATUS AND METHODS Patent Application
JOSEPH DOYCHAK, inventor (to NASA) and TONY PARROTT, inventor (to NASA) 16 Oct. 1992 20 p
(NASA-CASE-LEW-15430-1; NAS 1.71:LEW-15430-1; US-PATENT-APPL-SN-961943) Avail: CASI HC A03/MF A01

An apparatus and method for suppressing acoustic noise utilizes consecutive plates, closely spaced to each other so as to exploit dissipation associated with sound propagation in narrow channels to optimize the acoustic resistance at a liner surface. The closely spaced plates can be utilized as high temperature structural materials for jet engines by constructing the plates from composite materials. Geometries of the plates, such as plate depth, shape, thickness, inter-plate spacing, arrangement, etc., can be selected to achieve bulk material-like behavior. NASA

N93-17225# Lawrence Livermore National Lab., CA.
DUAL-BAND INFRARED IMAGING APPLICATIONS: LOCATING BURIED MINEFIELDS, MAPPING SEA ICE, AND INSPECTING AGING AIRCRAFT
N. K. DELGRANDE, P. F. DURBIN, and D. E. PERKINS Sep. 1992 8 p Presented at the Quantitative Nondestructive Evaluation Conference, San Diego, CA, 19-24 Jul. 1992
(Contract W-7405-ENG-48)
(DE93-000516; UCRL-JC-111214; CONF-9207155-1) Avail: CASI HC A02/MF A01

We discuss the use of dual-band infrared (DBIR) imaging for three quantitative NDE applications: location buried surrogate mines, mapping sea ice thicknesses, and inspecting subsurface flaws in aging aircraft parts. Our system of DBIR imaging offers a unique combination of thermal resolution, detectability, and interpretability. Pioneered at Lawrence Livermore Laboratory, it resolves 0.2 C differences in surface temperatures needed to identify buried mine sites and distinguish them from surface features. It produces both surface temperature and emissivity-ratio images of sea ice, needed to accurately map ice thicknesses (e.g., by first removing clutter due to snow and surface roughness effects). The DBIR imaging technique depicts subsurface flaws in composite patches and lap joints of aircraft, thus providing a needed tool for aging aircraft inspections. DOE

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SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

A93-20900
THE LEGAL STATUS OF EKRANOPLANES
STEFAN A. KAISER Air & Space Law (ISSN 0927-3379) vol. 17, no. 6 Dec. 1992 p. 286-290. refs
Copyright

The legal aspects involved in any future operation of ekranoplanes, defined as air cushion vehicles, e.g., hovercraft, which are able to operate at greater altitudes are presented. Attention is given to the technical aspects, the legal definition of aircraft, the functional approach, and the protection of third parties. Due to the altitudes they can attain and the requirement to coordinate flight path and altitude tri-dimensionally the safe operation of ekranoplanes should be ensured by the current requirements for aircraft and flight crews. R.E.P.

A93-21681
AERONAUTICAL ENGINEERING EDUCATION FOR THE ARMED FORCES
R. K. DUGGINS (University College, Canberra, Australia) Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering (ISSN 0954-4100) vol. 206, no. G2 1992 p. 137-142. refs
Copyright

A discussion is given of the arrangements that have been made for aeronautical and aerospace engineering education of members of the armed forces in the United Kingdom, the United States of America, West Germany and Australia. A striking feature of the comparisons is shown to be the extent of the differences in the arrangements in the various countries. A less detailed and less rigorous version of the paper was presented at the Aerotech 92 conference. Author

A93-22105
AN INDEX OF RESOURCE MATERIALS FOR AVIATION METEOROLOGY EDUCATION AND TRAINING
MICHAEL R. POELLOT (North Dakota Univ., Grand Forks) *In*

International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 16-18. refs
Copyright
The issues of training resource availability and information dissemination are addressed. The concept of a comprehensive index of training resources being implemented at the University of North Dakota is described. Results of a questionnaire concerning the resource material index concept are presented. P.D.

A93-22108
WEATHER FORECASTS FOR AVIATION IN CANADA (FACN AND FTCN) - THE WAY THEY ARE TAUGHT AND HOW THEY CAN BE MADE MORE SUITABLE TO THE NEEDS OF PILOTS
JEAN-GUY CANTIN (Environnement Canada, Saint-Laurent) and GILLES SANSCARTIER (Environnement Canada, Saint-Hubert) *In* International Conference on Aviation Weather Systems, 4th, Paris, France, June 24-28, 1991, Preprints Boston, MA American Meteorological Society 1991 p. 26-30. refs
Copyright
The pedagogical method used to train university graduates as weather forecasters, especially in aviation, is presented. The same forecast process is also valid for other types of forecasting, like public and marine forecasting. The work of the Atmospheric Environment Service of Environment Canada to improve the quality of its aviation weather services to users, private pilots in particular, is described. P.D.

A93-23016#
AIAA'S ROLE IN AEROSPACE EDUCATION
JAMES F. MARCHMAN, III (Virginia Polytechnic Inst. and State Univ., Blacksburg) and PATRICK GOUHIN (AIAA, Washington) Jan. 1993 8 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0324) Copyright
The current activities of AIAA related to aerospace education are reviewed from their origin to the present day. It is noted that AIAA is involved in a variety of educational activities including volunteer work in elementary and high school education, legislative action relating to education, and accreditation activities for engineering and technology. O.G.

A93-23017#
REFORM OF THE AERONAUTICS AND ASTRONAUTICS CURRICULUM AT MIT
E. F. CRAWLEY, E. M. GREITZER, S. E. WIDNALL, S. R. HALL, H. L. MCMANUS, J. R. HANSMAN, J. F. SHEA, and M. LANDAHL (MIT, Cambridge, MA) Jan. 1993 16 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 Research supported by MIT refs
(AIAA PAPER 93-0325) Copyright
A substantially revised undergraduate degree program developed by the Department of Aeronautics and Astronautics at MIT is described. Particular attention is given to the background and rationale for the new plan, objectives and requirements for the undergraduate education, the structure of the undergraduate program, and the differences with generally existing programs. O.G.

A93-23018#
TOTAL QUALITY MANAGEMENT IN CURRICULUM DEVELOPMENT
ROBERT C. WINN and ROBERT S. GREEN (U.S. Air Force Academy, Colorado Springs, CO) Jan. 1993 6 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0326)
The principles of Total Quality Management are briefly described focusing on the importance of identifying the customer and analyzing the processes. The 14 points of Dr. W. Edwards Deming, which form a framework for the implementation of the TQM are individually applied to the academic environment based on the experience gained at the Air Force Academy. It is noted that the key elements to a successfull TQM implementation include gain of the support in the chain of supervision, identification of customers, focus on the process, and Deming's 14 points as a guide and checklist during the implementation process. O.G.

A93-23344#
THE DESIGN OF A SENIOR-LEVEL CAD COURSE WITH EMPHASIS ON FLUID/THERMAL SYSTEMS
FOLUSO LADEINDE (New York State Univ., Stony Brook) Jan. 1993 13 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993 refs
(AIAA PAPER 93-0426) Copyright
This paper reviews the development of a proposed curriculum for a CAD course that places emphasis on fluid/thermal systems. Student preparation, contents and laboratory assignments for this new course are discussed. System synthesis (not just component design), utilization of computer-aided interface with tools for drafting, solid modeling, wireframes, CFD, and visualization issues are presented. R.E.P.

N93-16563# Manchester Univ. (England). Aeronautical Engineering Group.
AERONAUTICAL ENGINEERING GROUP PUBLICATIONS: 1950 - PRESENT
1991 30 p
(AERO-REPT-9108; ETN-92-92775) Avail: CASI HC A03/MF A01
The full title, name of author(s), and name of publication in which papers concerned with aeronautical engineering are found, are listed. Publications date from 1950 to present day. Not all of the reports are available for general distribution. ESA

N93-17091# Committee on Appropriations (U.S. Senate).
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
In its Departments of Veterans Affairs and Housing and Urban Development and Independent Agencies Appropriations for Fiscal Year 1993, Part 1 p 427-669 1992
Avail: CASI HC A11/MF A10; Subcommittee of the Committee on Appropriations, Senate, Washington, DC 20510 HC; SOD HC
This second of two NASA parts of H.R. 5679 presents testimony to review the proposed fiscal year 1993 NASA budget. Some specific budget items discussed were the Space Station Freedom, the Assured Crew Return Vehicle, the Advanced Solid Rocket Motor, the National Aerospace Plane (NASP), the Landsat program, aeronautical research and technology, the American space program and U.S. competitiveness. Questions and answers regarding the NASA budget are then presented. As part of the testimony, the Payload Flight Assignments, NASA Mixed Fleet for January 1992 is included. Participants of the JOVE program (NASA/university joint venture in space sciences) are included. Also listed are the participants in the NASA Space Grant College and Fellowship Program. R.L.B.

N93-17325*# Pittsburgh State Univ., KS. Dept. of Engineering Technology.
INDUSTRY SURVEY OF SPACE SYSTEM COST BENEFITS FROM NEW WAYS OF DOING BUSINESS
RUSSELL L. ROSMAIT *In* Alabama Univ., 1992 NASA/ASEE Summer Faculty Fellowship Program 3 p Dec. 1992
Avail: CASI HC A01/MF A03
The cost of designing, building and operating space system hardware has always been expensive. Small quantities of specialty parts escalate engineering design, production and operations cost. Funding cutbacks and shrinking revenues dictate aggressive cost saving programs. NASA's highest priority is providing economical transportation to and from space. Over the past three decades NASA has seen technological advances that provide grater efficiencies in designing, building, and operating of space system hardware. As future programs such as NLS, LUTE and SEI begin, these greater efficiencies and cost savings should be reflected in the cost models. There are several New Ways Of Doing Business (NWODB) which, when fully implemented will reduce space system costs. These philosophies and/or culture changes are integrated

in five areas: (1) More Extensive Pre-Phase C/D & E, (2) Multi Year Funding Stability, (3) Improved Quality, Management and Procurement Processes, (4) Advanced Design Methods, and (5) Advanced Production Methods. Following is an overview of NWODB and the Cost Quantification Analysis results using an industry survey, one of the four quantification techniques used in the study. The NWODB Cost Quantification Analysis is a study performed at Marshall Space Flight Center by the Engineering Cost Group, Applied Research Incorporated and Pittsburg State University. This study took place over a period of four months in mid 1992. The purpose of the study was to identify potential NWODB which could lead to improved cost effectiveness within NASA and to quantify potential cost benefits that might accrue if these NWODB were implemented. Author

N93-17891# TRW-Warner Robins, GA. Electronic Systems Group.
TECHNICAL OPERATING REPORT ON THE DATA INTEGRATION AND COLLECTION ENVIRONMENT (DICE) INSTRUMENTATION SYSTEM DESIGN Interim Report, May 1991 - May 1992
Jun. 1992 26 p
(Contract F04606-89-D-0040)
(AD-A258444; WL-TR-92-1068) Avail: CASI HC A03/MF A01

Current and planned avionics radar systems are highly sophisticated in their capabilities and heavily dependent on Embedded Computer Systems (ECS) for their operation. Avionics radar systems containing ECS provide a high level of flexibility in both system configuration and capability. However, increased flexibility requires increased logistical support. This support includes both hardware and software maintenance. Air Force Logistics Command (AFLC) is conducting a concentrated effort to limit the rising cost of ECS support while responding to user requests for improving these systems. This effort and the ECS Support Improvement Program (ESIP), a program implemented to address the problem of developing a rapid turnaround capability for airborne avionics radar systems, have as one of their research and development objectives to develop the necessary rapid turnaround capabilities to support mission critical ECS. Rapid Turnaround (RT) is defined as correcting a system deficiency in a timely fashion through some combination of software, firmware, and/or hardware modifications. The RT concept evolved from the overall AFLC objective to decrease the time and resources required to implement operational or maintenance changes in deployed ECS. Avionics systems are designed with internal data buses which can provide access to vast amounts of data. The data buses contain data, such as MIL-STD-1553 and H009, and are located primarily in the programmable signal processor. The need for an instrumentation system hosted on-board a tactical aircraft resulted in the development of the Data Integration and Collection Environment (DICE) System by TRW and the Air Force. GRA

N93-18087# Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Systems and Logistics.
APPLYING COMMERCIAL STYLE ACQUISITION PRACTICES TO THE PROCUREMENT OF COMMERCIALLY AVAILABLE AIRCRAFT M.S. Thesis
DOUGLAS W. HUMERICK and STEVEN H. MINNICH Sep. 1992 192 p
(AD-A258143; AFIT/GCM/LSY/92-6) Avail: CASI HC A09/MF A02

This study was performed to recommend which commercial acquisition practices should be adopted in government acquisitions of commercially available aircraft. Previous studies, dating to 1972, illustrate the value of adopting commercial style acquisition practices in government acquisitions. Using commercial style acquisition practices can provide the government with lower costs and faster delivery with no sacrifice of quality. As a customer of the aircraft manufacturing community, the government must adapt to global market changes. Procedure reviews and changes must occur on an ongoing basis to take advantage of standard industry practices. Telephone interviews of nineteen top level personnel representing twelve domestic aircraft manufacturers revealed difficulties encountered in selling to the government: oversight and bureaucracy; payment practices; contract complexity; clause application; and MILSPEC's which go beyond FAA certification requirements. A qualitative analysis methodology was selected and recommendations for commercially available aircraft acquisitions include the following points: creating a separate regulation to govern use of commercial practices; using commercial payment practices; requiring cost benefit analysis for MILSPEC's and MILSTD's which exceed FAA certifications; removing CAS requirements; establishing a commercial advocate similar to the position of competition advocate; relying on commercial marker forces to ensure the manufacturers produce at a low cost and sell at a fair price; and empowering program managers and contracting officers to keep decisions at the lowest possible level to streamline the decision making process. GRA

N93-18762*# Garrett Corp., Phoenix, AZ.
ADVANCED TURBINE TECHNOLOGY APPLICATIONS PROJECT (ATTAP) Annual Report, 1991
Jun. 1992 149 p Sponsored by DOE, Washington, DC
(Contract DEN3-335)
(NASA-CR-189228; NAS 1.26:189228; REPT-31-8071(04); DOE/NASA/0335-4) Avail: CASI HC A07/MF A02

This report is the fourth in a series of Annual Technical Summary Reports for the Advanced Turbine Technology Applications Project (ATTAP). This report covers plans and progress on ceramics development for commercial automotive applications over the period 1 Jan. - 31 Dec. 1991. Project effort conducted under this contract is part of the DOE Gas Turbine Highway Vehicle System program. This program is directed to provide the U.S. automotive industry the high-risk, long-range technology necessary to produce gas turbine engines for automobiles with reduced fuel consumption, reduced environmental impact, and a decreased reliance on scarce materials and resources. The program is oriented toward developing the high-risk technology of ceramic structural component design and fabrication, such that industry can carry this technology forward to production in the 1990s. The ATTAP test bed engine, carried over from the previous AGT101 project, is being used for verification testing of the durability of next-generation ceramic components, and their suitability for service at Reference Powertrain Design conditions. This document reports the technical effort conducted by GAPD and the ATTAP subcontractors during the fourth year of the project. Topics covered include ceramic processing definition and refinement, design improvements to the ATTAP test bed engine and test rigs and the methodology development of ceramic impact and fracture mechanisms. Appendices include reports by ATTAP subcontractors in the development of silicon nitride and silicon carbide families of materials and processes. Author

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GENERAL

A93-19976
AEROSPACE '92 - THE YEAR IN REVIEW
RUDOLF DECHER, ANTHONY W. STRAWA, MICHAEL R. FISKE, BRUNO L. LOHMUELLER, VERN SCHMIDT, MAHENDRA C. JOSHI, JOSEPH S. LE GATH, MICHAEL POLITES, PEGGY DUGGE, JOHN HODGKINSON et al. Aerospace America (ISSN 0740-722X) vol. 30, no. 12 Dec. 1992 p. 10-25, 28-39, 41-48 (29 ff.).
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This comprehensive evaluation of aerospace scientific and industrial achievements during 1992 encompasses aeroacoustics, air-breathing propulsion, flight mechanics, CAD-CAM, communications, computer systems, digital avionics, flight simulation and testing, fluid dynamics, general aviation, guidance

and navigation, and the atmospheric environment. Also discussed are advancements in airship design, liquid and solid rocket propulsion, nuclear thermal propulsion, airborne sensors, software, space automation and robotics, astronomy, structures and their dynamics, aircraft survivability, terrestrial energy systems, and V/STOL aircraft design. O.C.

A93-22276#
KEYNOTE ADDRESS - ADVANCED TECHNOLOGY DEMONSTRATORS, PROTOTYPES AND HYPERSONIC FLIGHT
J. SWIHART (Swihart Consulting, Inc., Bellevue, WA) Dec. 1992 5 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992
(AIAA PAPER 92-4999) Copyright

In his speech to the 4th International Aerospace plane conference the author points out that space belongs not to the individual nations but to all mankind and a cooperative effort is needed to explore, build, and utilize it jointly. One internationally designed, built, and operated economical spaceplane is needed to save the limited resources of the world. O.G.

A93-22308*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A HISTORICAL PERSPECTIVE ON HYPERSONIC RESEARCH AT THE NACA/NASA LANGLEY RESEARCH CENTER (1944-1984)
DAVID E. REUBUSCH (NASA, Langley Research Center, Hampton, VA) Dec. 1992 17 p. AIAA, International Aerospace Planes Conference, 4th, Orlando, FL, Dec. 1-4, 1992 refs
(AIAA PAPER 92-5034) Copyright

A survey of some of the highlights on hypersonic research and technology development conducted at NASA Langley Research Center are presented. Attention is given to the range of disciplines that are being and have been explored at Langley. This review is also intended to supplement previous surveys written around one particular discipline while this survey covers a range of disciplines. R.E.P.

A93-23005*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
THE X-15 AIRPLANE - LESSONS LEARNED
WILLIAM H. DANA (NASA, Flight Research Center, Edwards, CA) Jan. 1993 14 p. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993
(AIAA PAPER 93-0309) Copyright

The X-15 rocket research airplane flew to an altitude of 354,000 ft and reached Mach 6.70. In almost 200 flights, this airplane was used to gather aerodynamic-heating, structural loads, stability and control, and atmospheric-reentry data. This paper describes the origins, design, and operation of the X-15 airplane. In addition, lessons learned from the X-15 airplane that are applicable to designing and testing the National Aero-Space Plane are discussed. Author

N93-16464# Manchester Univ. (England). Aeronautical Engineering Group.
LANCHESTER: THE MAN
J. A. D. ACKROYD 1991 67 p Presented at the Lanchester Lecture for Royal Aeronautical Society Coventry Branch, England, 18 Sep. 1991
(AERO-REPT-9111; ETN-92-92776) Avail: CASI HC A04/MF A01

A lecture given at the Royal Aeronautical Society to celebrate the memory of Frederick William Lanchester is presented. A biographical sketch is given, and Lanchester's work on the following is discussed: motorcar engineering, aerodynamics, boundary layer theory, lift and drag wing theory. In the appendix the following are addressed: the vortex theory of lift, the vortex, the sine alpha incidence relation. ESA

N93-16652*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
1991 RESEARCH AND TECHNOLOGY Technical Memorandum, Fiscal Year 1991
Oct. 1992 349 p LIMITED REPRODUCIBILITY: More than 20% of this document may be affected by color photographs Original contains color illustrations
(NASA-TM-103924; A-92063; NAS 1.15:103924) Avail: CASI HC A15/MF A03; 30 functional color pages

Selected research and technology activities at Ames Research Center, including the Moffett Field site and the Dryden Flight Research Facility, are summarized. These activities exemplify the Center's varied and productive research efforts for 1991. Author

N93-17890# Air War Coll., Maxwell AFB, AL.
DR. ALEXANDER H. FLAX: TECHNOLOGIST OF AERONAUTICS
LEGAND L. BURGE Mar. 1992 58 p
(AD-A258441) Avail: CASI HC A04/MF A01

This paper is a tribute to the unique contribution of Dr. Alexander H. Flax who served from 1963 to 1969 as Assistant Secretary for Research and Development, US Air Force. A number of pioneering efforts concerning aircraft flight have affected the Air Force. Since its beginning great innovators have emerged who improved upon the art and science of flight. One such person is Al Flax. This article identifies, describes, and assesses Flax's contributions to the field of aeronautics and to the United States Air Force's science and technology program. The study is based on open sources, research, and oral history interviews regarding Flax's life. Air power and the control of the battlefield offered by airborne equipment and personnel owe much to Flax's work. Flax contributed to decisive elements of aerospace power, aerodynamics and aeronautics. Rotorcraft, wide-body aircraft, aircraft materials, and spacecraft. GRA

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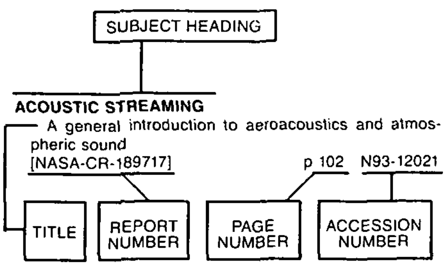

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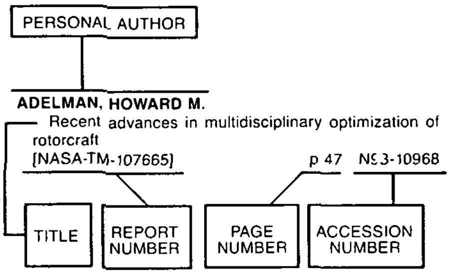

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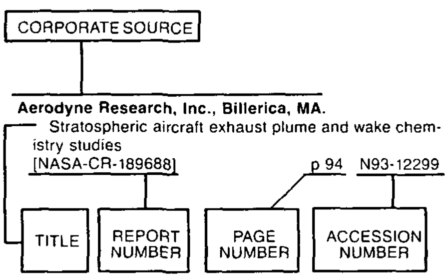

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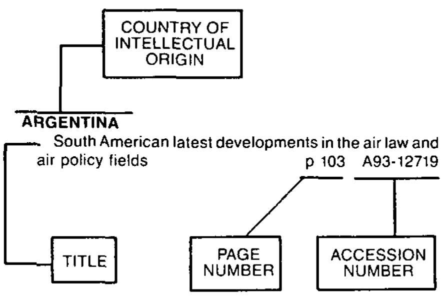

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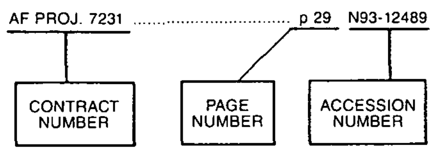

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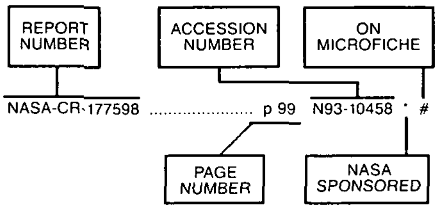

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A93-11272 * # p 38

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